Pilot Test and Bench-scale Studies of Arsenic Removal by Adsorptive Media

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Albuquerque, NM

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Outline of Talk

- Background – why we have a new Arsenic MCL.
- Arsenic Water Technology Partnership
  - Screening of technologies for pilot studies
  - Sandia Labs Pilot Test program
- Frontiers of Science
  - Understanding media performance
  - Rapid testing techniques
- What this all means in the real world-
  - Helping communities deal with the new Standard
  - Sandia arsenic website
  - NM Small Business Assistance Program

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Sandia Labs Arsenic Team Members

- Malynda Aragon – lead field engineer
- Alicia Aragon – RSSCT studies
- Melody Nocon, Hongting Zhao – lab studies
- Randy Everett, William Holub Jr., Brian Dwyer,
- Jerome Wright, Justin Marbury, Emily Wright, Michelle Shedd, Carolyn Kirby, Paul McConnell, Linnah Neidel, Nik Rael, Andres Sanchez, David Stromberg, Zac Satterfield
- Prof. Shuguang Deng, New Mexico State

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‘The King of Poison and the Poison of Kings’

Mass poisoning by arsenic - the premier global public health problem?

- **Skin Cancer, Skin lesions**
- **Bladder Cancer**
- **Lung Cancer**
- **Cardiovascular Disease**
- **Blackfoot Disease**

These are result of exposure to relatively high doses over extended period of time.

Other effects of concern include diabetes, cancers of liver and kidney, birth defects, developmental problems

No immediate danger from low doses!

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Background for 2006 MCL for Arsenic

- 2006 Reduction of drinking water Maximum Concentration Level (MCL) for arsenic from 50 ppb to 10 ppb was intended to reduce incidence of bladder cancer and other cancers in US.
- Southwestern United States is characterized by high and variable background levels for arsenic
- Estimated national annual costs of implementing 10 ppb MCL range from $165M to $605M to save 7 – 33 lives.
  - $5M – $23.9M /life saved
  - $1.3M – $6.6M/ year of life saved
    - About 1 life/500,000 exposed persons per year
- New MCL is controversial due to high costs and uncertain health benefits.

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Populations Studies are Ambiguous

- **Studies prior to 2001 Standard**
  - **Some studies carried out in populations in Taiwan, South America show elevated bladder cancer risks. (“relative risk” = 5 –11).**
  - **As concentrations were generally above 50 μg/L.**
  - **Results of studies of US and European populations at lower As concentrations show no increased risk or are ambiguous.**

- **Post-2001 studies**
  - **Results: *do not* suggest that chronic exposures to arsenic at low levels (50 – 100 μg/L) lead to increased mortality risk for bladder or lung cancer for the majority of populations studied.**
  - **Some studies suggest interaction between smoking and exposure to arsenic ***may*** lead to increased risk for bladder and lung cancers;**
    - **Smokers may experience a higher risk at levels below 100 μg/L**
  - **Elevated bladder cancer *incidence* in New Mexico at >10 μg/L suggested recently**
  - **Potential role of arsenic in endrocrine disruption, developmental disorders**

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Unintended Consequences of new MCL for Arsenic

- The health effects from income redistribution may have adverse health consequences.
  - $90/month additional cost for rural NM household
- Injury risks from water treatment may exceed the benefits.
  - Based on traffic accident statistics and distance from chemical supply sources for treatment
  - Results depend on assumed dose-response model and treatment technology
- Rural water utilities may cease to operate.
- Rural residents may switch from a public supply to a unregulated private well.

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Key Questions

- Is my system or private well likely to have elevated levels of arsenic?
- What are the best methods to remove arsenic to comply with new MCL?
- How can I figure out the answer the question #2?

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Is a high level of arsenic likely?

What controls distribution and behavior of arsenic in the environment?

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Volcanic Sources of Arsenic

- Strongly enriched in volcanic gases compared to magma
  - enrichment factor = 1000 - 1000000
- Abundant in silicic volcanics
  - derived volcaniclastic sediments
  - associated hydrothermal systems
    - As is a pathfinder elements in prospecting for hydrothermal gold deposits

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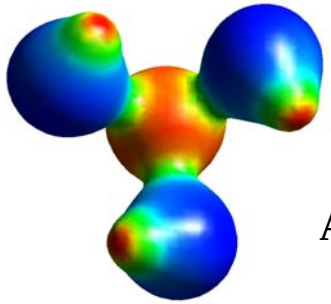
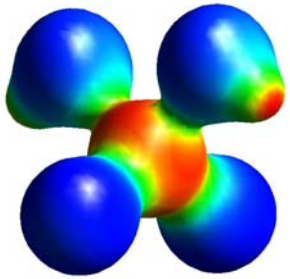
Increase of Arsenic in Natural Waters

- Reductive dissolution of iron oxides
  - co-release of adsorbed and structural As
- Reductive desorption of As(V)
  - strongly sorbed As(V) -> weakly sorbed As(III)
- Competitive desorption
  - phosphate, bicarbonate, silicate, dissolved organics
- pH changes
  - increased pH leads to As(V) desorption



As(III)

H_3AsO_3



As(V)

$H_2AsO_4^-$

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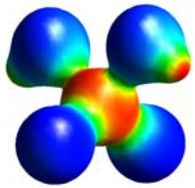
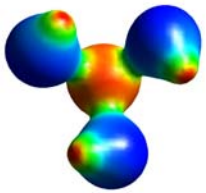
pH, Speciation, and Sorption





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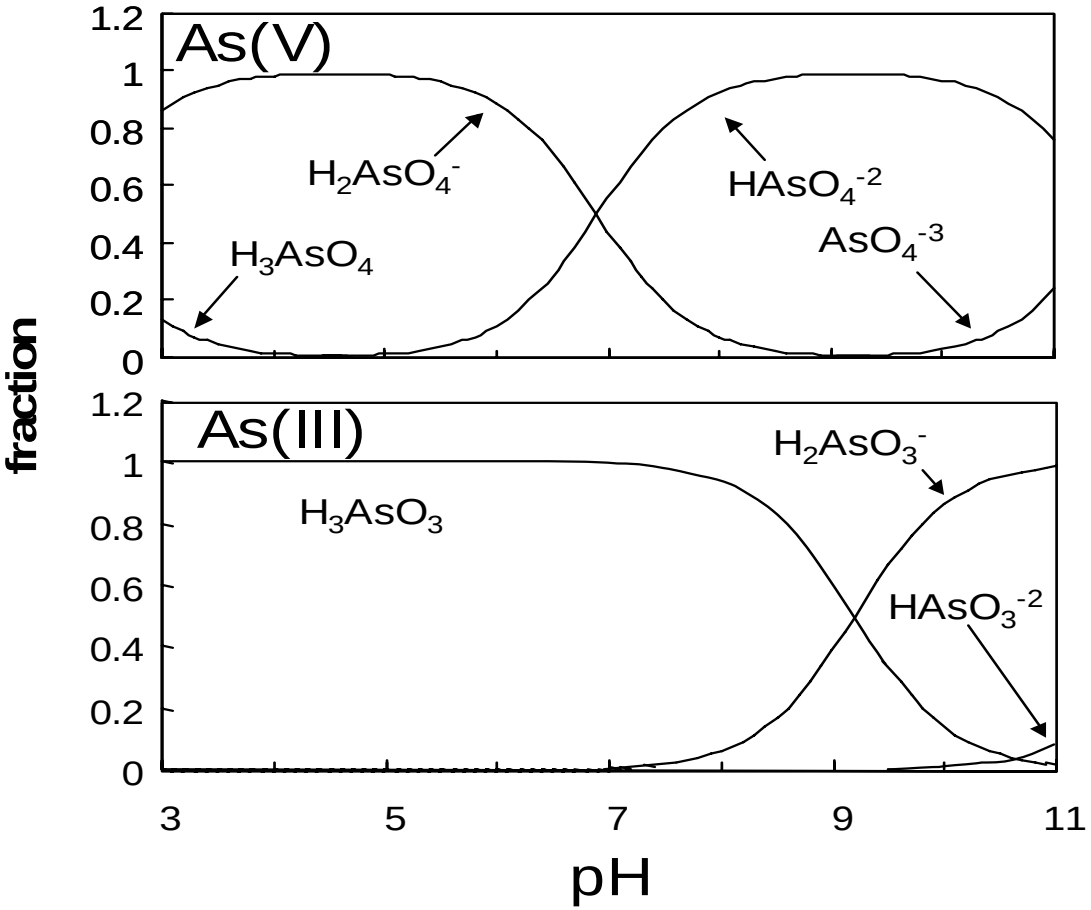
More sorption



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Less sorption

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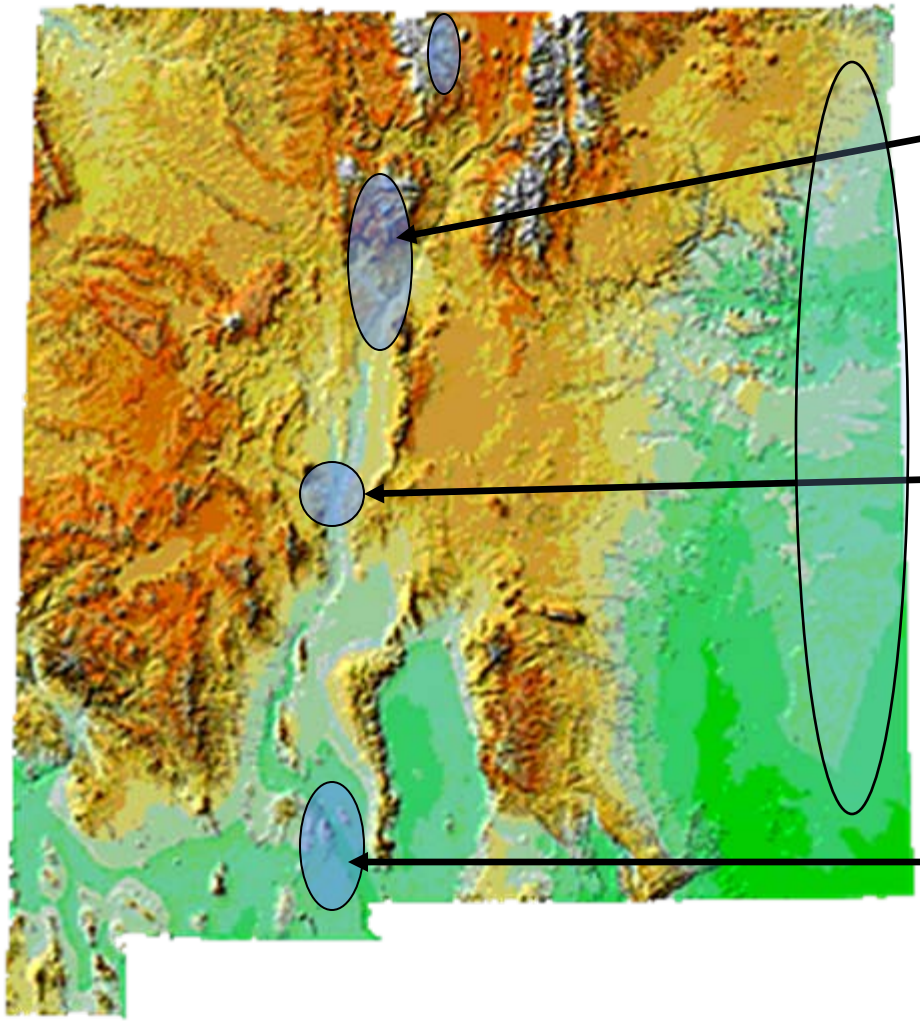
High Arsenic in New Mexico's Waters



- **Abundant in silicic volcanics**
  - **– derived volcaniclastic sediments and associated hydrothermal systems**
- **Arsenic enrichment by Potassium Metasomatism**
  - **low temperature alteration common in closed hydrographic basins in arid climates**
- **Mixing of deep geothermal waters and shallower surface influenced waters**

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What is the best method to remove arsenic?

Is there a magic bullet?

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Can advances in water treatment technology significantly reduce costs?

Arsenic Water Technology Partnership

- **Congressional Appropriation - $13M FY03 – FY06**
- **DOE- funded peer-reviewed, cost-shared research program to develop and demonstrate innovative technologies for removal and disposal of arsenic from drinking water**

- **Partner Roles**
  - **Bench-Scale Studies (AwwaRF)**
  - **Demonstration Studies (Sandia)**
  - **Economic Analysis/Outreach (WERC)**
- **Focus on small systems**
  - **40% of resources directed to rural and Native American utility needs**
  - **Minimize costs - capital, operating, maintenance**
  - **Minimize residual quantities & disposal costs**

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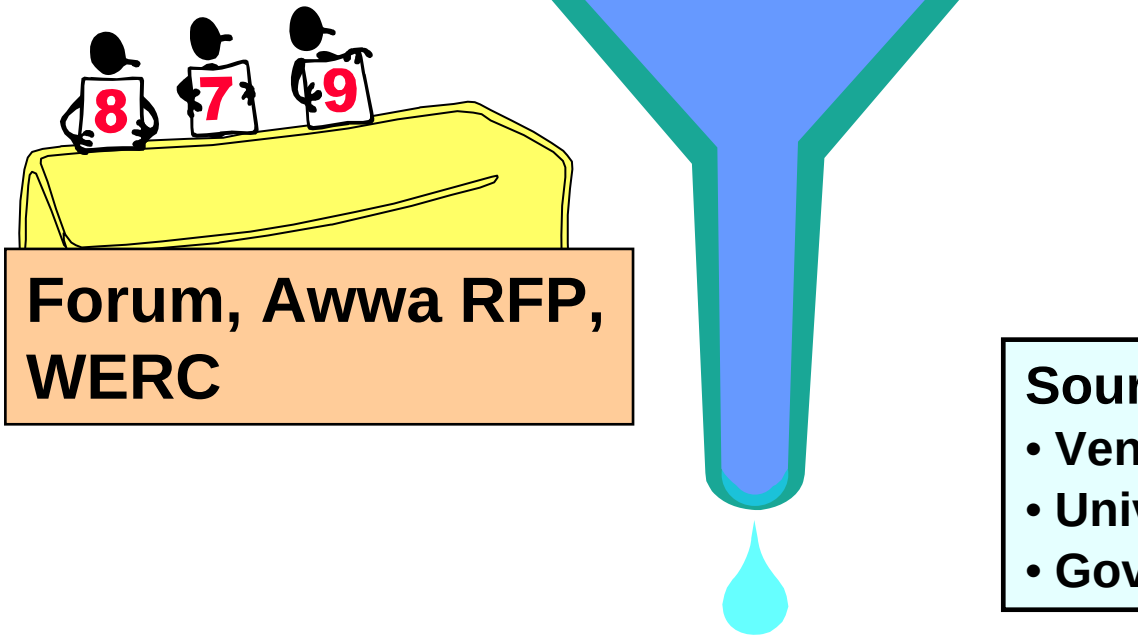
AWTP Technology Screening Process



Forum, Awwa RFP, WERC

- Innovation
- Performance
- Cost
- Complexity
- Maturity

Sources of new technologies
- **Vendors**
- **Universities**
- **Government labs**

Suggested Pilot Technologies

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AWTP Technology Screening Programs

- **Sandia Arsenic Treatment Vendors Forum**
  - Open session allows Vendors to present product descriptions
  - Closed session review by Technical Evaluation Teams
- **Awwa Research Foundation**
  - Technical Review Committee defines research objectives
  - Grants are awarded through competitive, peer-reviewed RFP process
- **WERC Design Contest**
  - WERC utilizes its existing Design Contest in order to obtain innovative arsenic removal technologies.

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Sandia Vendor Forum Description

- **Held at *New Mexico Environmental Health Conferences* in Albuquerque, 2003-2005.**

- **Format**
  - **Public presentations by vendors.**
  - **Vendors privately interviewed by *Technology Evaluation Teams***
    - **Four five-person teams of water treatment experts at each Forum.**
    - **Each vendor interviewed by at least two teams.**

- **Twenty-seven different vendors evaluated at the three Forums.**
  - **Nine vendors in 2003, twelve in 2004, ten in 2005.**
  - **Four of the 27 vendors attended two Forums.**
  - **Two universities were among the 27 vendors.**

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Top Five Ranked Vendors at Forums

2003	2004	2005
Hydroglobe – TiO_2	Purolite – Hybrid resin	Purolite Hybrid resin
MEI - ZrO_2	BASF- GFO	ResinTech
Kinetico *C/F*	*Filtronics* *C/F*	EaglePicher – La-coated DE
AdEdge – GFO (Severn Trent)	DOW – TiO_2	ADA – Coated silicate
Filtronics *C/F*	ResinTech – Hybrid resin	Virotec – mixed oxides from Bauxite

Report is available.

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Innovations –industry and academia

- **Fe, Ti, Cu, Zr or mixed metal oxides in granules formed by chemical precipitation or nanoparticle agglomeration. (e.g. AdEdge, Kemiron, Argonide, Graver)**
- **Coating granular activated carbon (GAC), strong base anion exchangers resin or polymeric ligand exchangers with nanoparticulate metal oxides. (e.g. Purolite, Resintech, Auburn University, Arizona State)**
- **Coating inexpensive natural media or waste products with metal oxides or other functional groups. (e.g. ADA, Virotec, Lawrence Berkeley Labs)**
- **Increased surface area and chemical selectivity based on fibrous or gel substrates coated by metal oxides or materials with sulfhydryl functional groups. (e.g. NMSU, Weber State, Drexel University)**

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Sandia Pilot Test Concepts

- **Side-by-side demonstrations of technologies tested by AwwaRF bench-scale program, WERC design contest, University programs, or commercial technologies vetted through Vendor Forums**
  - **Test duration: 3 – 9 months; longer, if multiple pilots at same site**
  - **Test size: 0.3 – 2 gpm**
  - **Different technology classes: adsorptive media, Coagulation/Filtration, *membranes***
  - **Cooperative effort between Sandia, Technology Owner and Site Owner**
- **Test Protocols developed with help from NSF International, academia, industry during 2004-2005**

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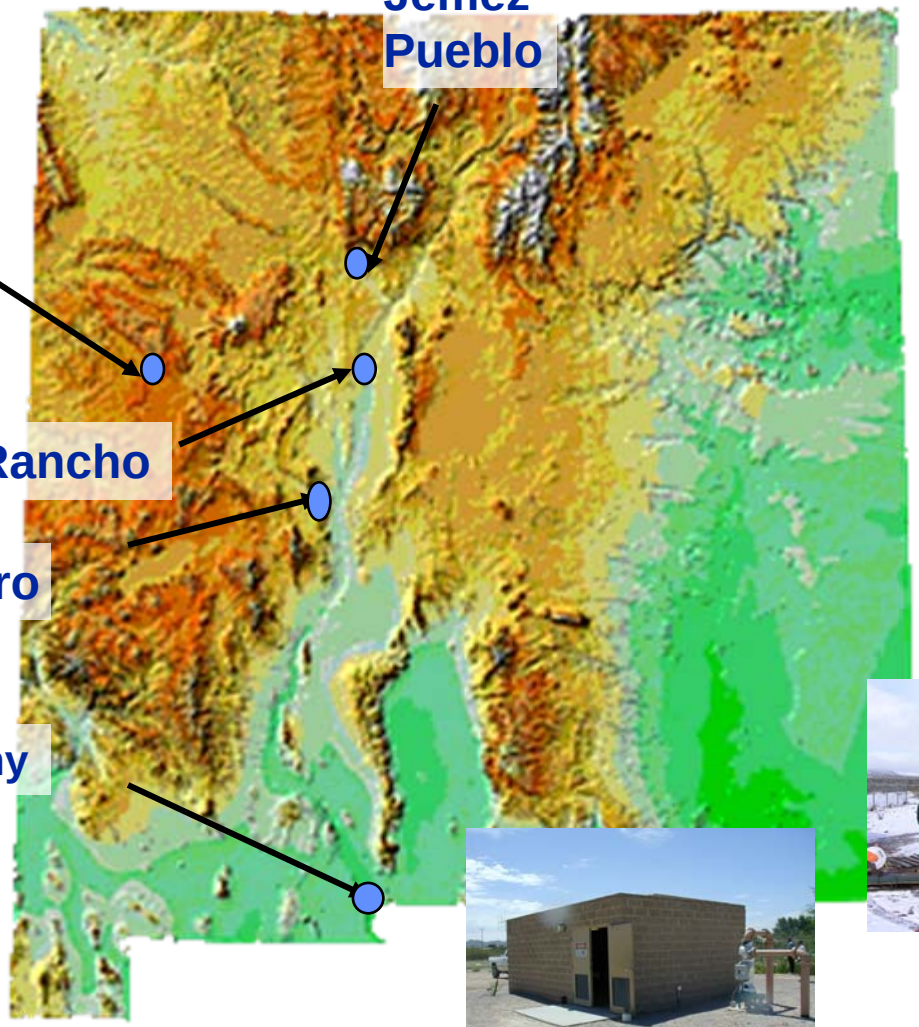
Test Sites in New Mexico



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New Mexico Pilot Sites – Water Quality

Site	Total As/As(III)	V (ppb)	SO_4 (ppm)	Fe (ppm)	pH
Socorro	*42 ppb / 0 ppb*	*11*	*29*	*0.4*	*8.0*
Anthony	20 ppb / 18 ppb	2	180	0.15	7.7
Rio Rancho	19 ppb / < 1 ppb	15	100	<0.10	7.7
Jemez Pueblo	20 ppb / 19 ppb	<1	24	1.2	7.5

Site	Cond. (μS/cm)	TOC (ppm)	Ca Hard (ppm $CaCO_3$)	Alkalinity (ppm $CaCO_3$)	SiO_2 (ppm)
Socorro	*360*	*0.5*	*44*	*120*	*25*
Anthony	1380	0.8	66	180	37
Rio Rancho	630	ND	62.5	184	22
Jemez Pueblo	770	2.0	155	290	50

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First Community Pilot: Socorro, NM

- 100% groundwater source for drinking water
- 2 warm springs (90^{o}F) provide 500 gpm, 35 – 55 ppb As(V) by gravity flow.
- Formerly site of tap for bottled water company;
- Optimal F for oral health
- Phase 1: Feb-Oct 2005
  - Tested
    - Fe oxides: ED33, ARM200
    - Resin - AsX^{np}
    - Ti-oxide - Metsorb
    - Zr-oxide - Isolux
  - EBCT study of E33
    - 2,4,5 min

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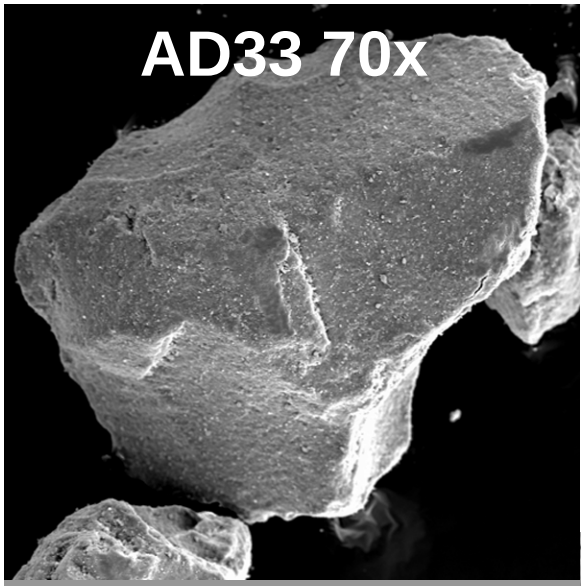
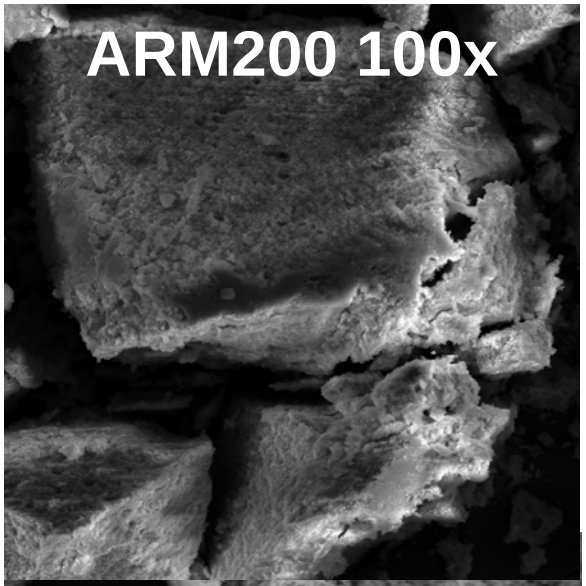
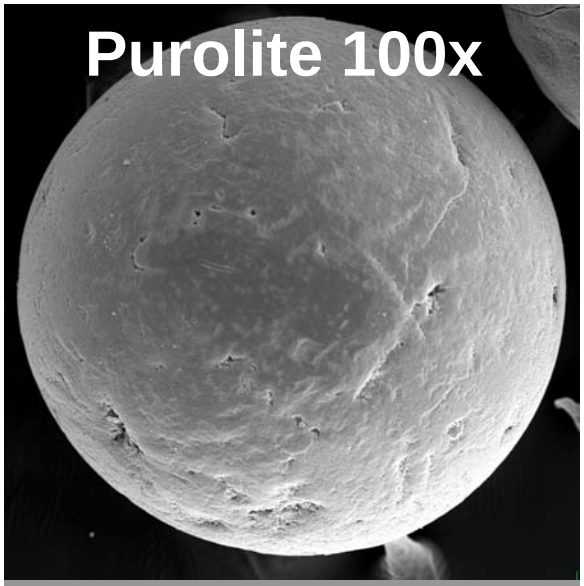
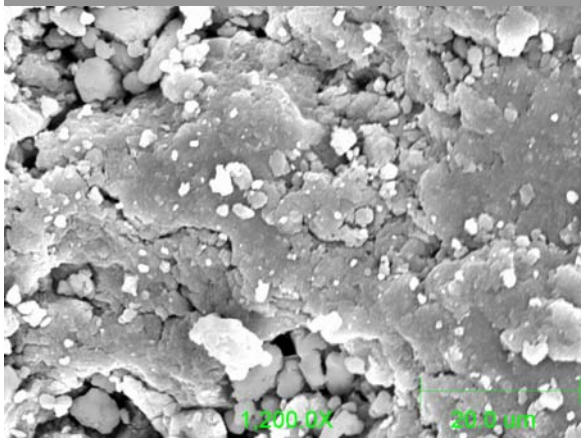
SEM Photos of Adsorptive Media

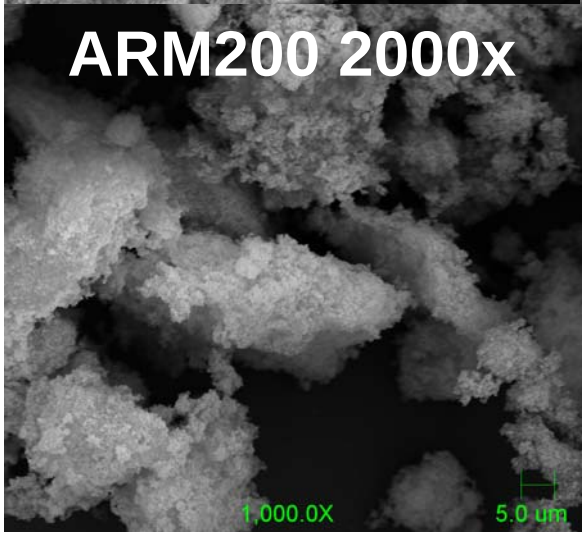




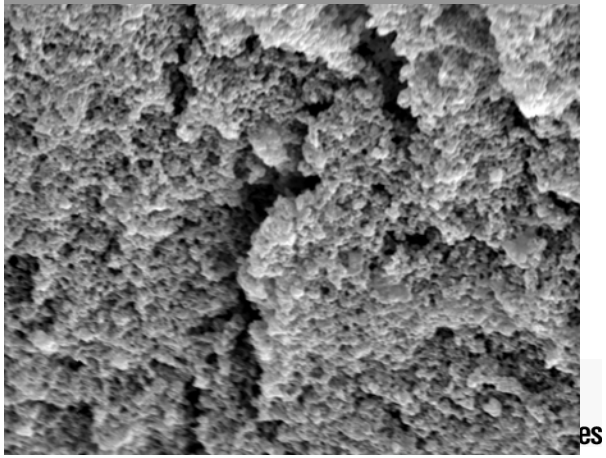


AD33 1200x

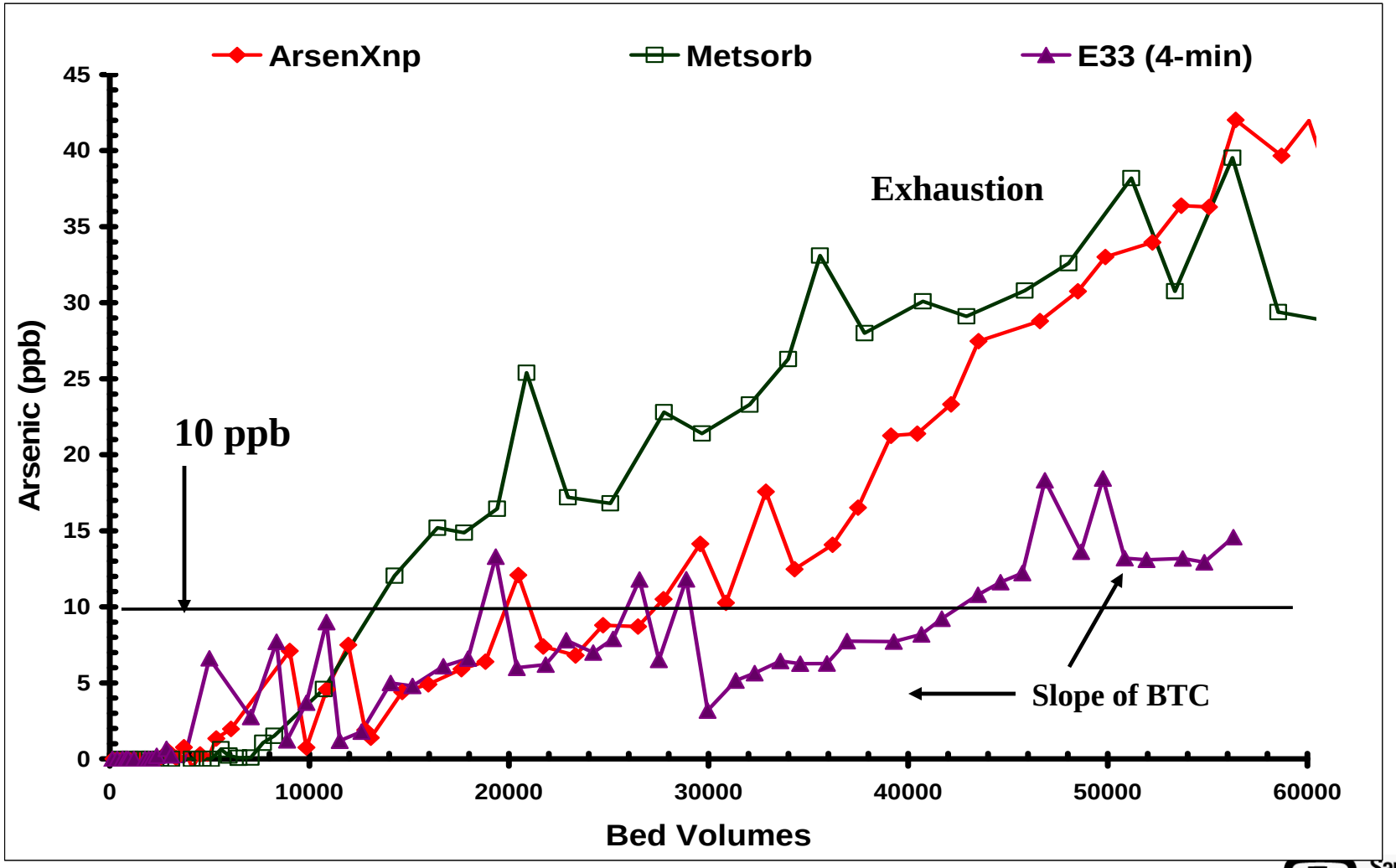




Purolite 1200x



Different ways to describe performance



*AsXnp batch was defective, ARM200 was pre-production batch

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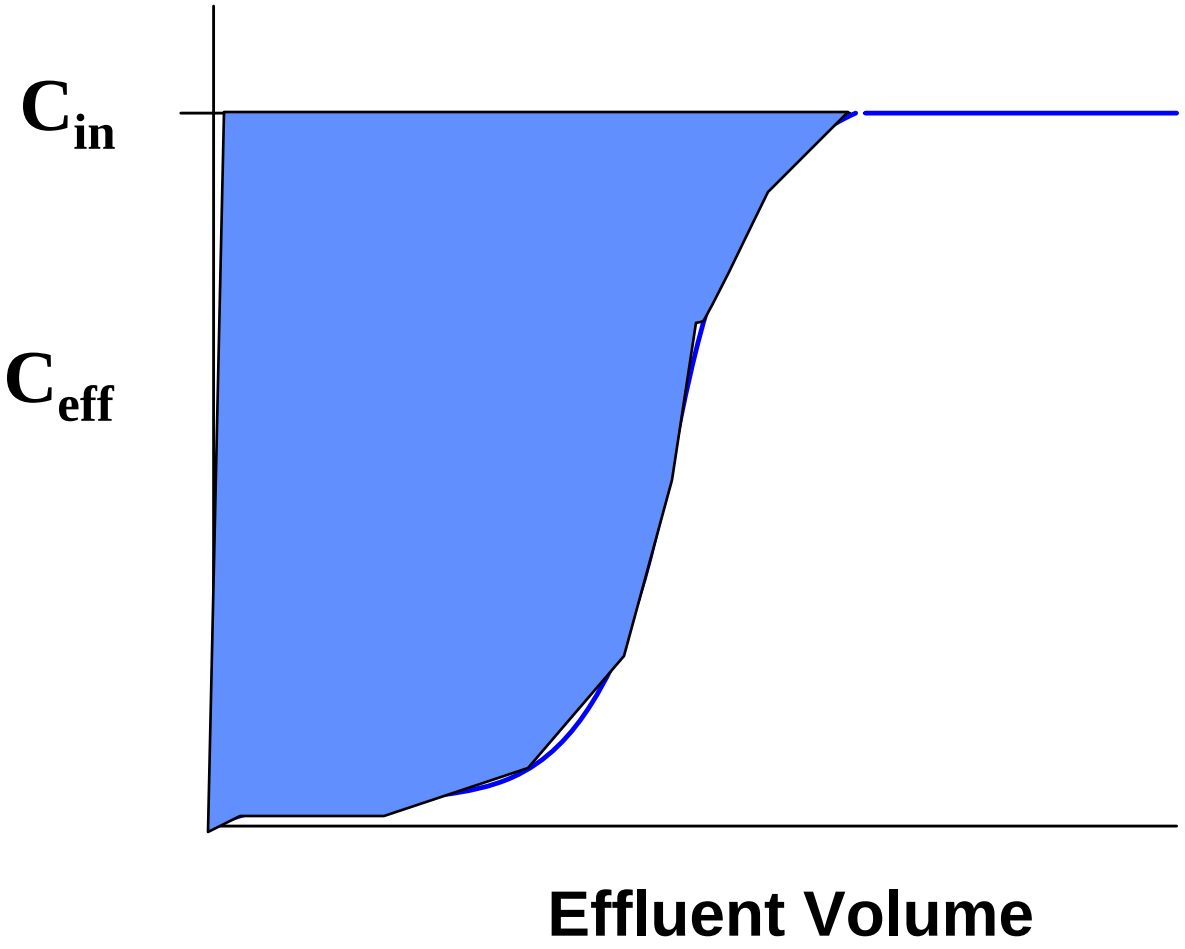
Calculation of Column Arsenic Loading Capacity



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Media Performance in Socorro, NM

- **Arsenic Removal Capacity**

Parameter	*ARM200 FeOx	Metsorb - TiOx	*AsX^{np}	Isolux ZrOx	E33 (FeOx)
BV to 10 ppb	8,600	13,000	27,000	32,000	43,000
Capacity at 10 ppb, mg/g	0.60	0.70	1.38	1.67	3.56
BV at C/Co = 0.8	33,000	87,000	53,000	63,000	>63,000
Capacity at C/Co = 0.8	1.15	2.26	2.10	2.23	> 4.62

*AsX^{np} batch was defective, ARM200 was pre-production batch

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Media Performance in Socorro, NM Phase 2b (Ambient pH vs. pH 6.8)

Phase 2b:

- **Side-by side comparisons of 5 media at 2 pH levels (ambient and pH 6.8)**
  - **ArsenX^{np} – New, QC'd batches**
  - **Isolux – larger cartridge**
  - **Kemiron – FeOx media—CFH-12**
  - **SANS – Sandia proprietary media**
  - **Metsorb – TiOx media**
- **Evaluate inadvertent effects of treatment**
  - **Loss of pH control**
  - **Loss of flow**
- **Evaluate AwwaRF & University media (pH 6.8)**
  - **AwwaRF: Auburn University (Poly-lig-IX), ASU (Fe-GAC)**
  - **University Media: NMSU (Solgel), NMT (coated-volcanic)**

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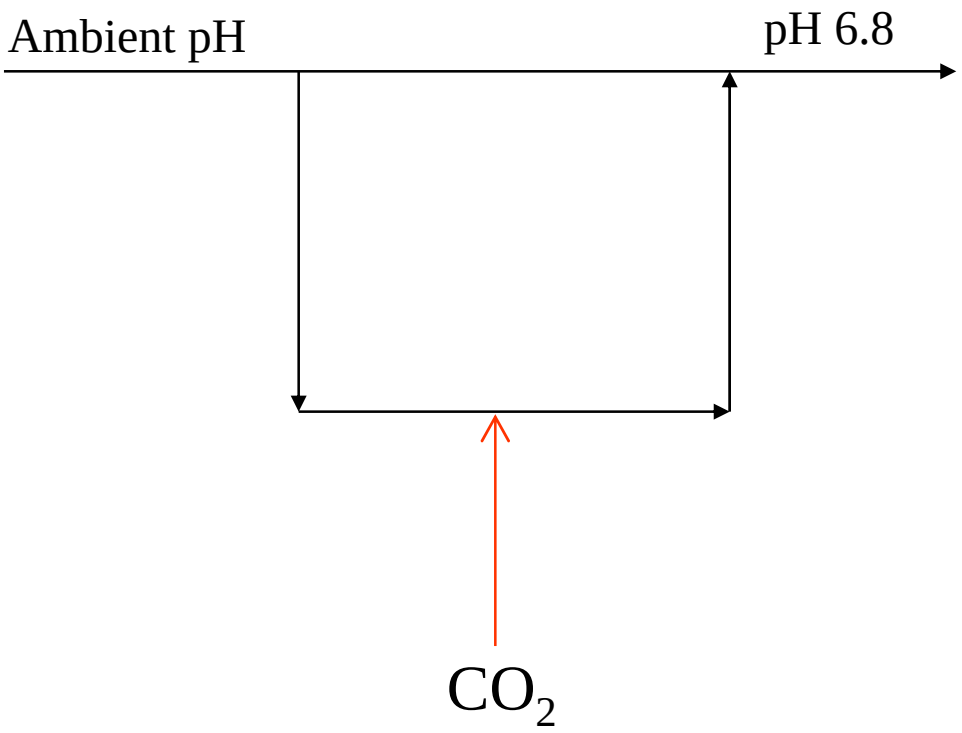
Media Performance in Socorro, NM

Phase 2b (Ambient pH vs. pH 6.8)

Phase 2b:

- **pH Adjustment using CO_2 gas**



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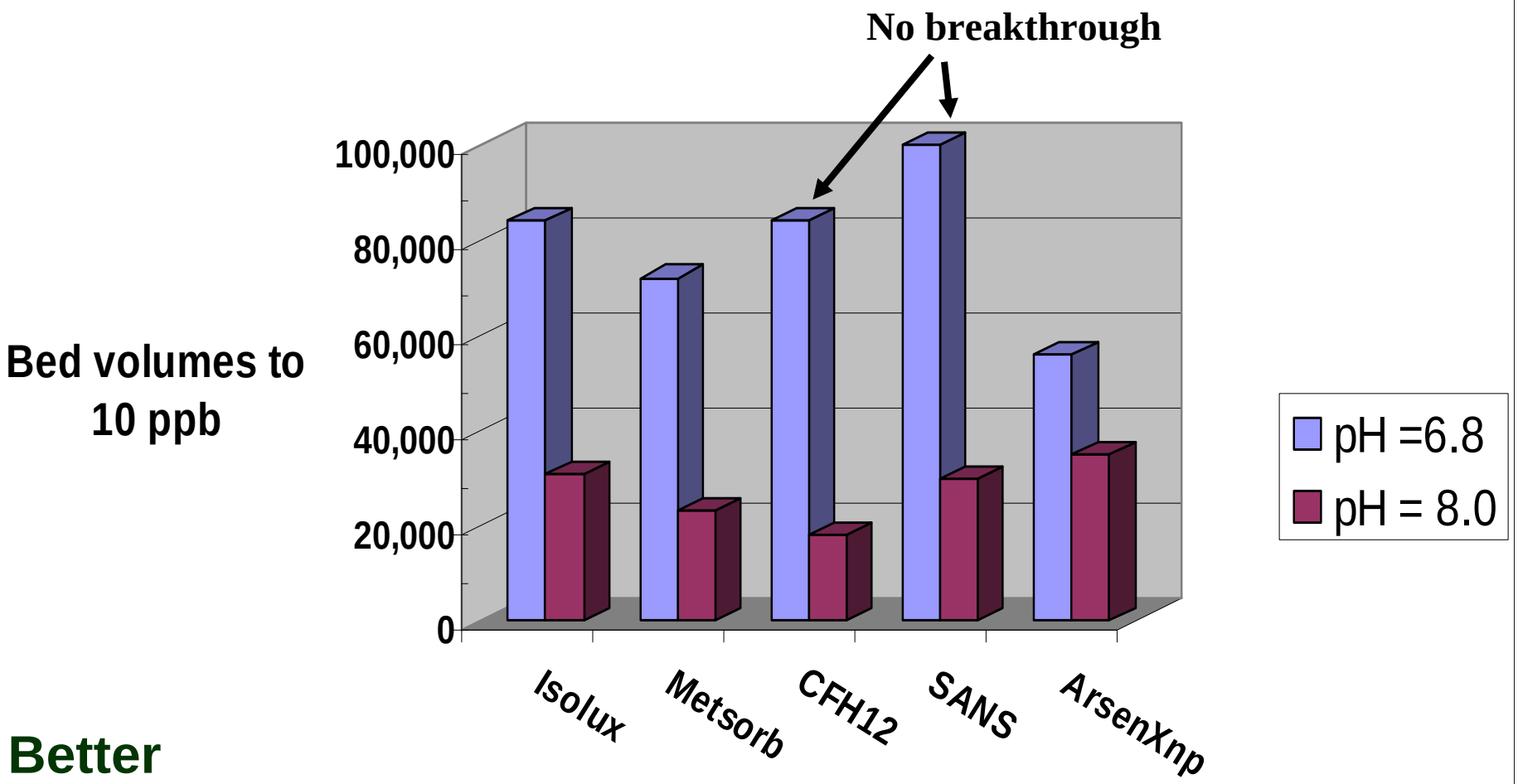
Media Performance in Socorro, NM
Phase 2 (pH = 6.8 vs. 8)



Better performance at lower pH.

Second Community Pilot: Anthony, NM

- 100% groundwater source for drinking water
- Warm springs (~85^{o}F) provide 240-270 gpm, 20 ppb As - mainly As(III).
- High sulfates, TDS
- Intermittent Flow Operation
- 4 Phases included 13 different sorbent media

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Second Community Pilot: Anthony, NM
(Desert Sands MDWCA)

- **Phase 1: August 2005**
  - FeOx: E33, ARM200, CFH12
  - ZrOx: Isolux
  - TiOx: Metsorb, Adsorbsia
  - SANS: mixed oxides
  - Resins: ASM-10HP, ArsenX^{np}
  - La, Fe, Mg-coated diatomaceous earth: NXT-2
- **Phase 2: December 2005**
  - FeOx-Coated GAC
  - Fe-coated silicate
  - Also: re-loaded ArsenX^{np} column
- **Phase 3: June 2006**
  - La, Fe, Mg-coated diatomaceous earth: NXT-2
  - Modified zeolite: Redisorb
  - New batch ARM200

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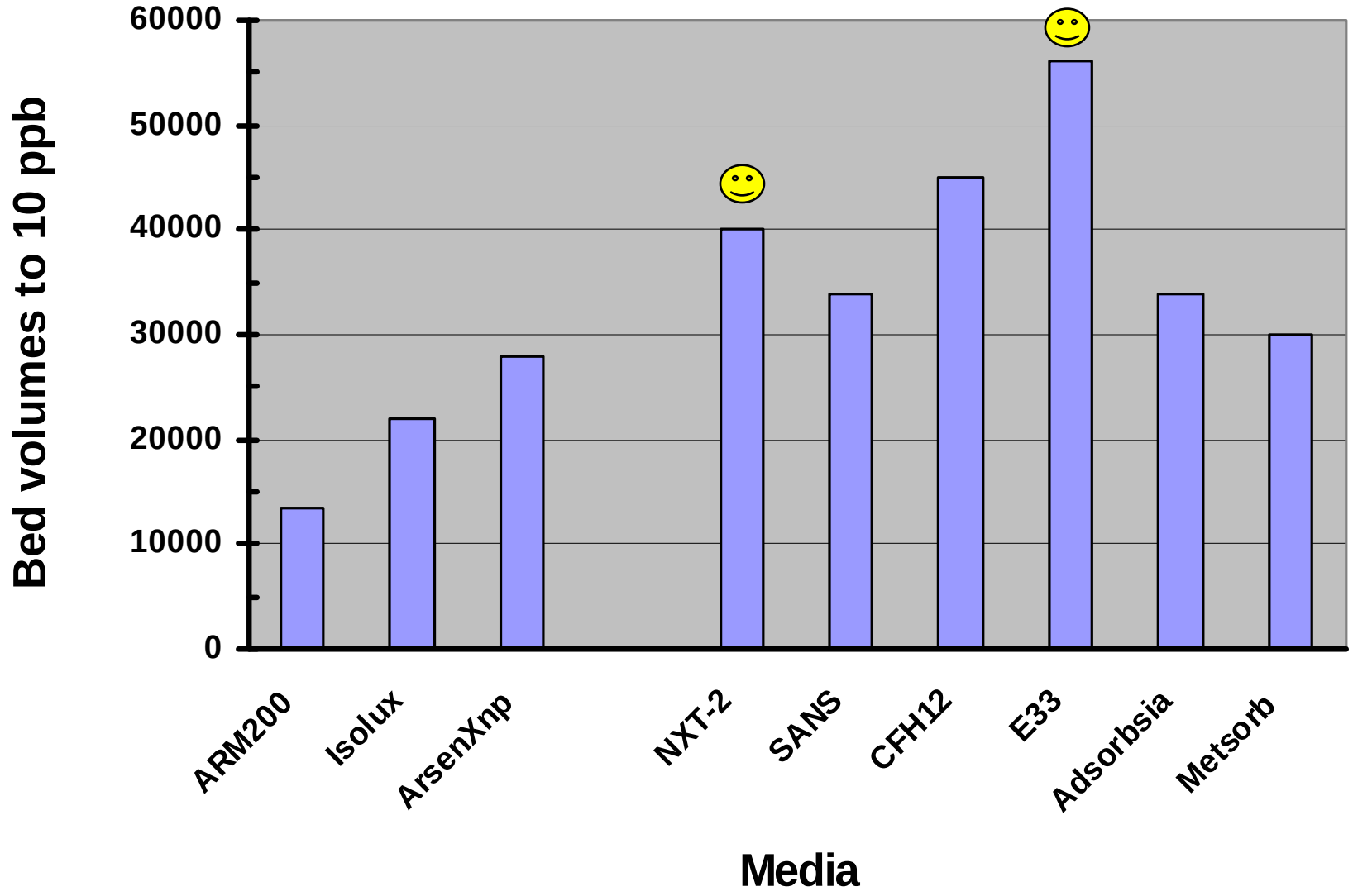
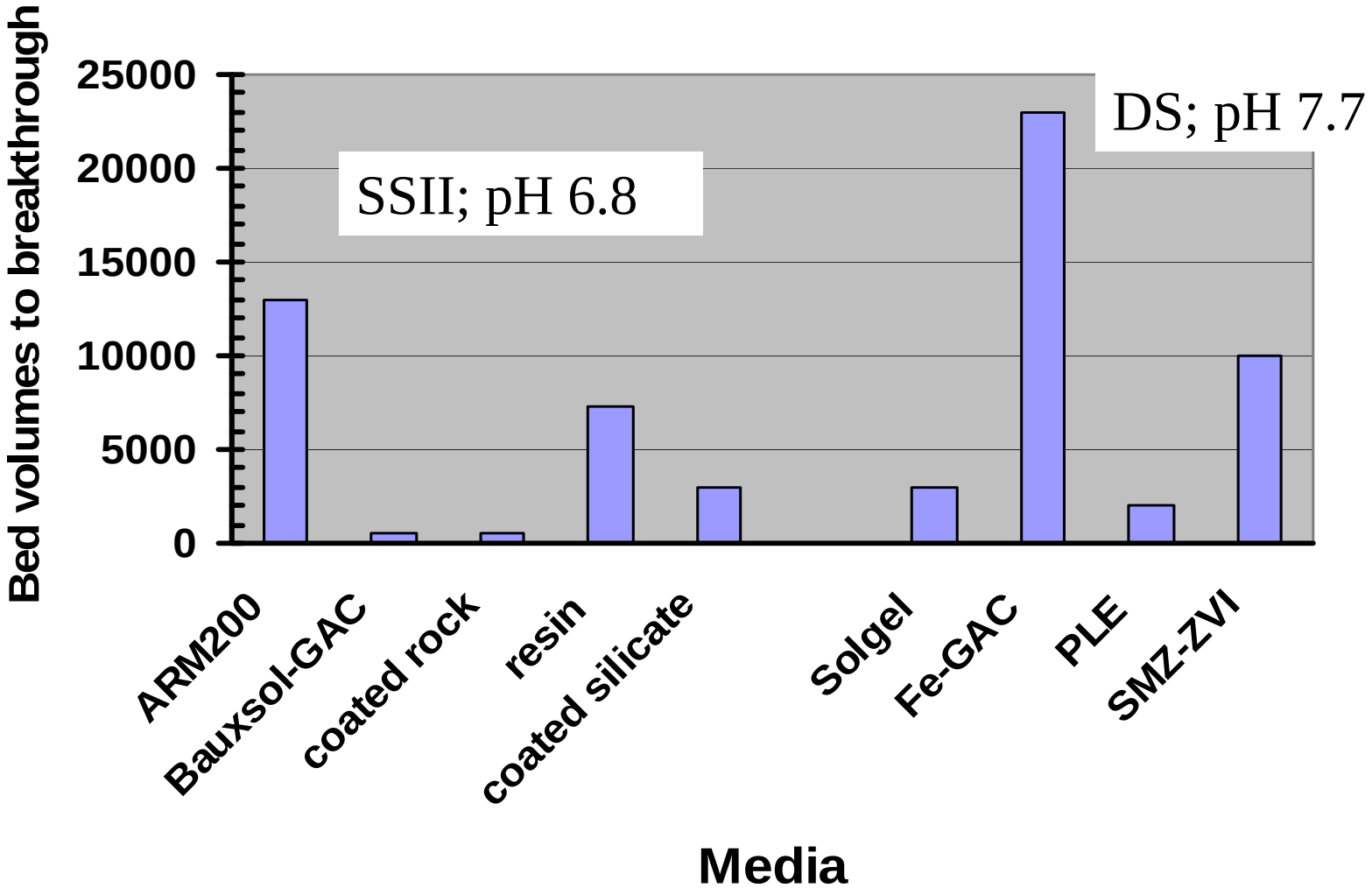
Best Results of Desert Sands Study

(final phases not completed)



Results from Studies of “Experimental” Media



Outline of Talk

- Background – why we have a new As MCL.
- Arsenic Water Technology Partnership
  - Screening of technologies for pilot studies
  - Sandia Labs Pilot Test program
- **Frontiers of Science**
  - **Understanding media performance**
  - **Rapid testing techniques**
- What this all means in the real world-
  - Helping communities deal with the new Standard
  - Sandia arsenic website
  - NM Small Business Assistance program

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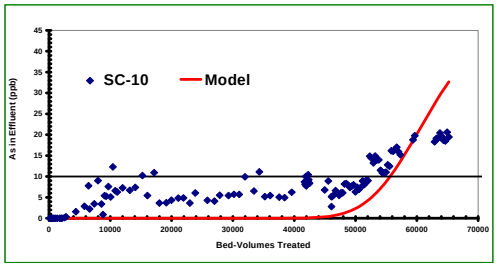
Research Program - Overall Objective

Develop rapid testing methods and models to reduce time and costs required to determine the most effective adsorptive treatment technology for small systems.

Full scale treatment
12-24 months

Pilot scale
6-12 months

RSSCT & isotherm
Days-weeks



Models: days- hrs

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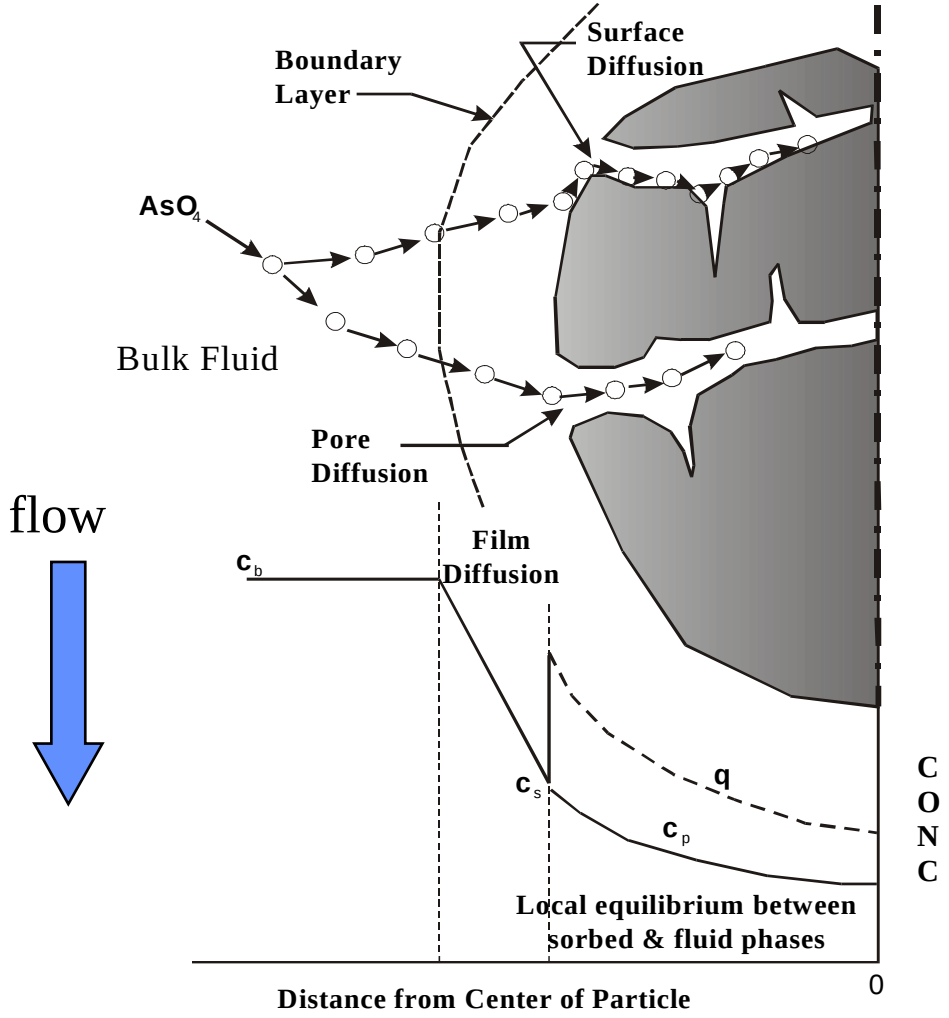
Performance of Adsorptive Media



Controlling factors

- Sorption equilibria
- Intraparticle diffusion rates
- Uniform flow

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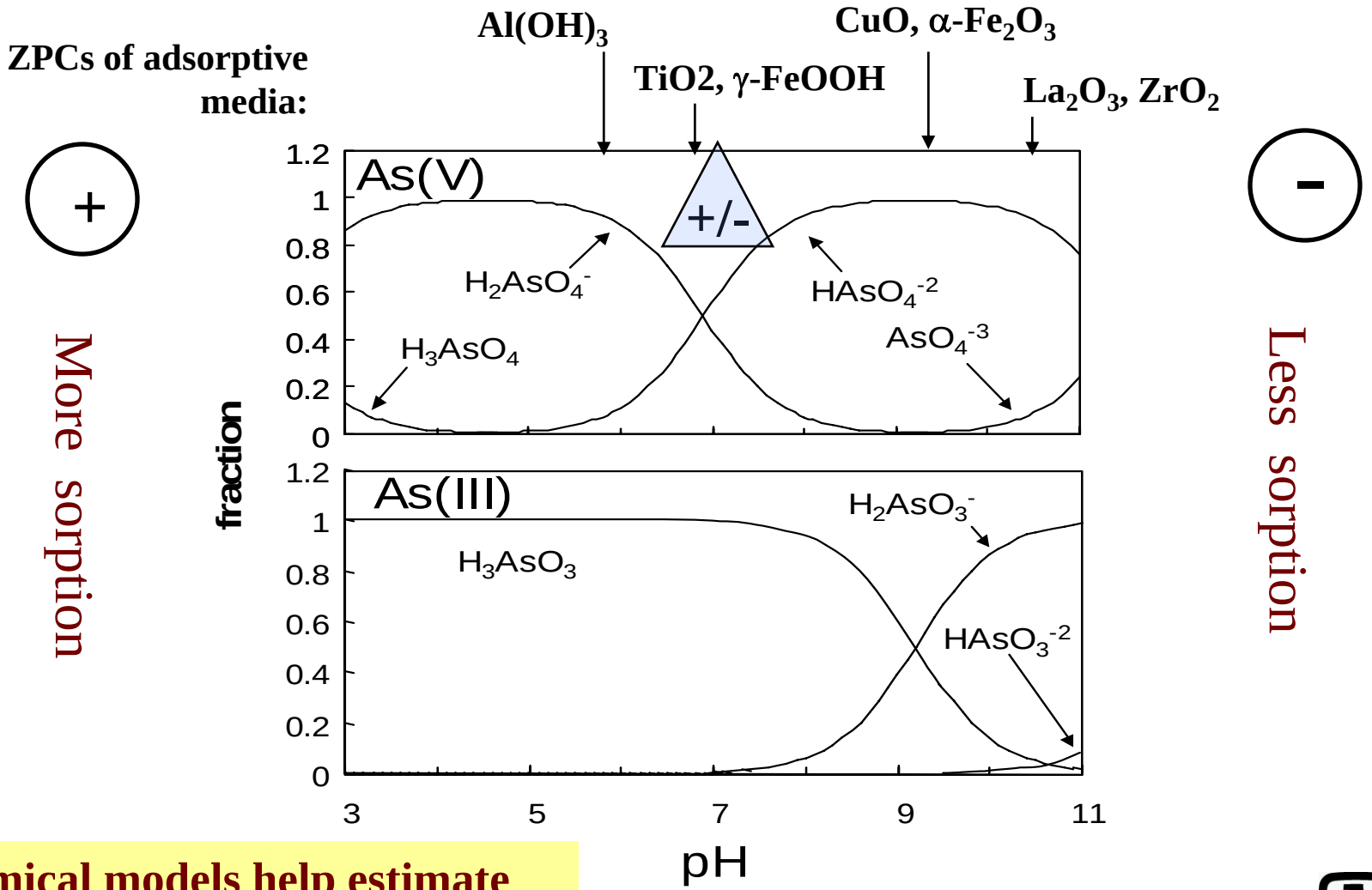
pH, Speciation, and Sorption



Chemical models help estimate relative performance.

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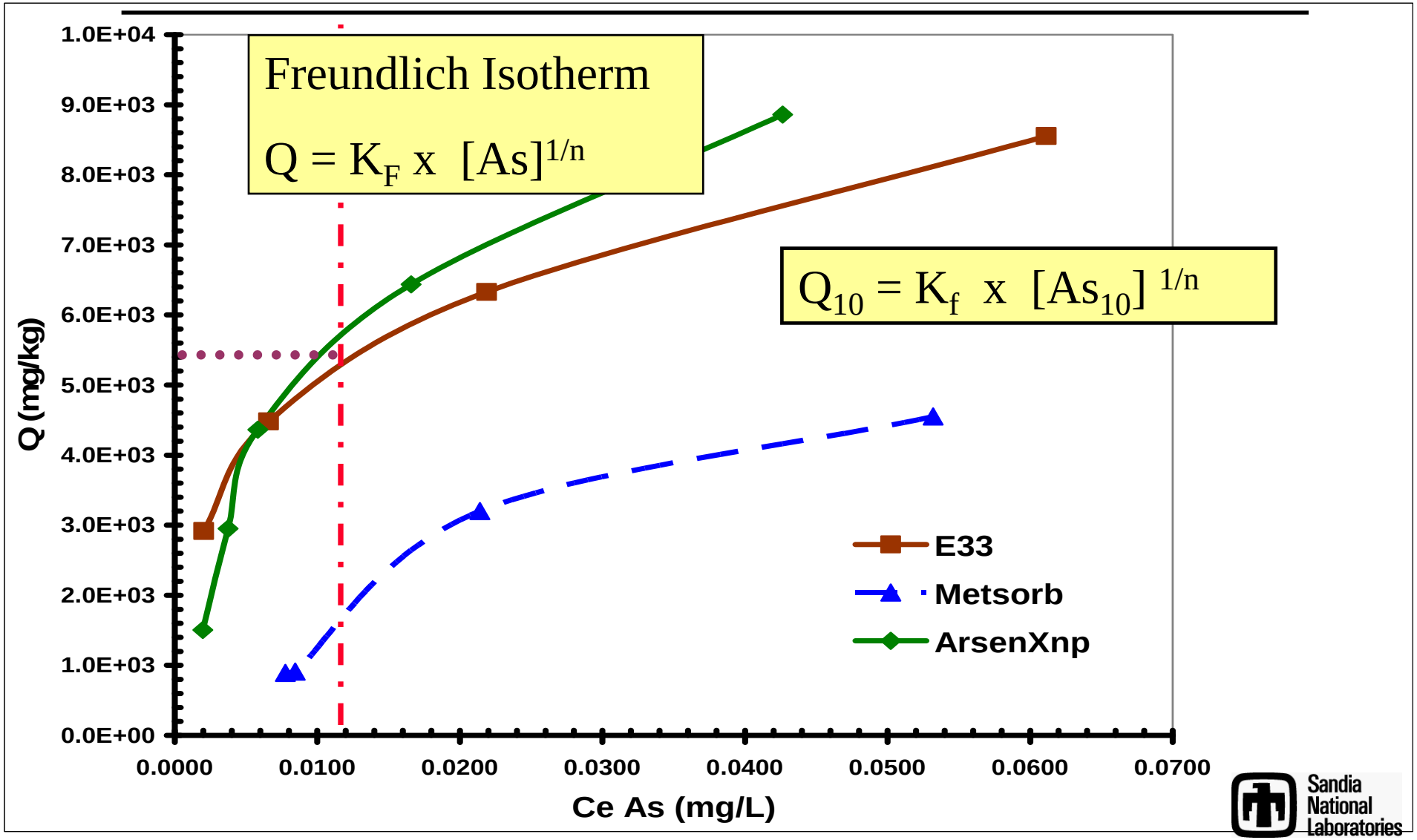
Batch Isotherm Results (Socorro, NM)



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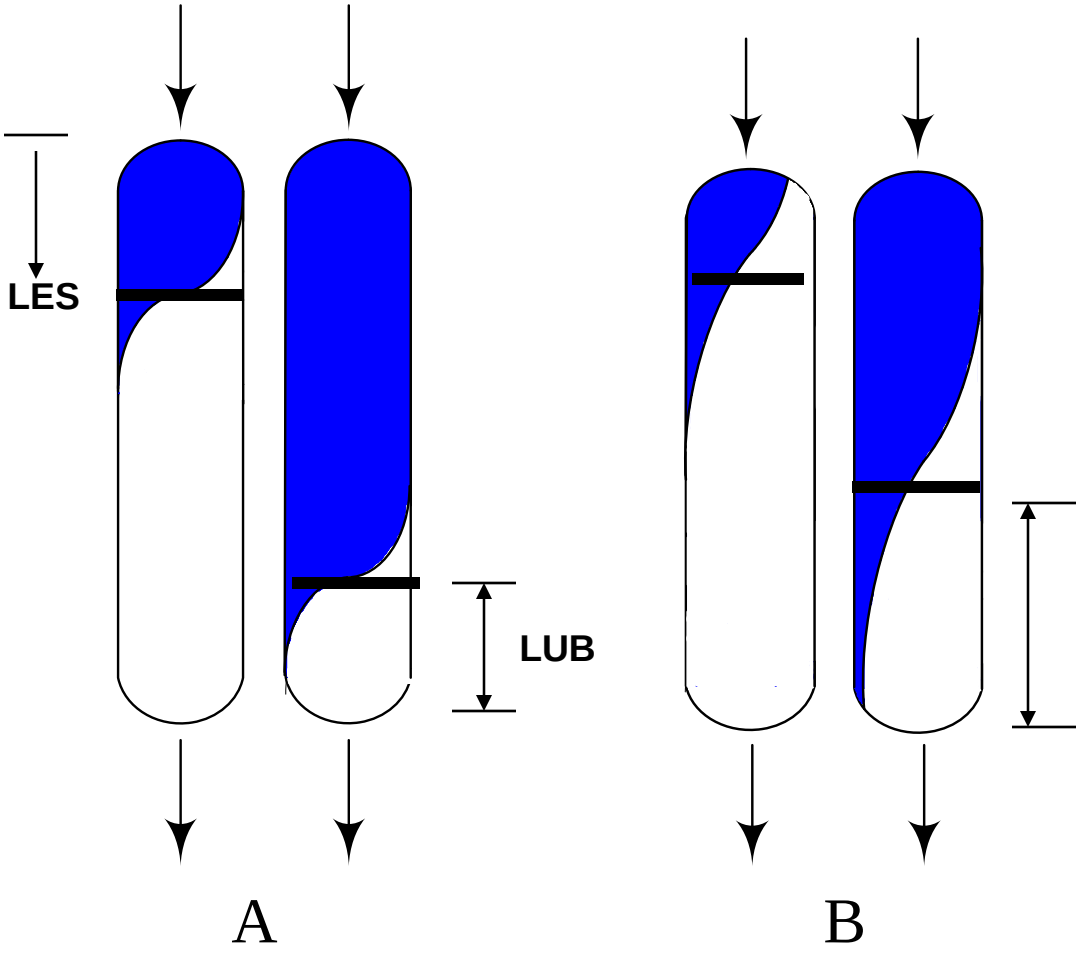
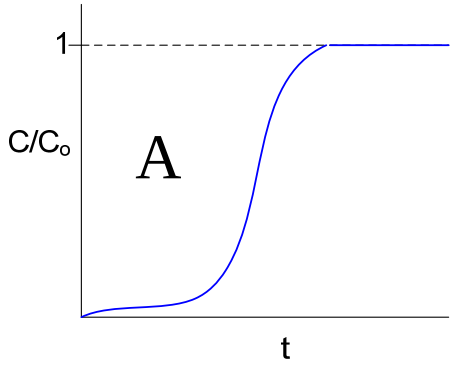
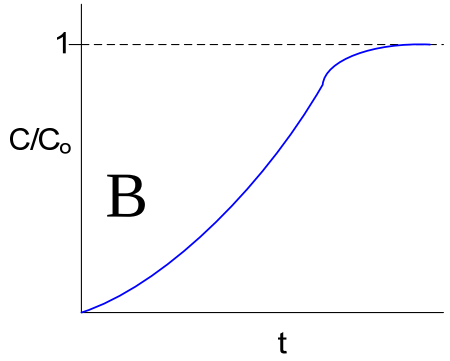
Sorption isn't the whole story: Shape of mass transfer zone determines capacity





Later breakthrough



Earlier breakthrough

LES = Length of Equilibrium Bed LUB = Length of Unused Bed

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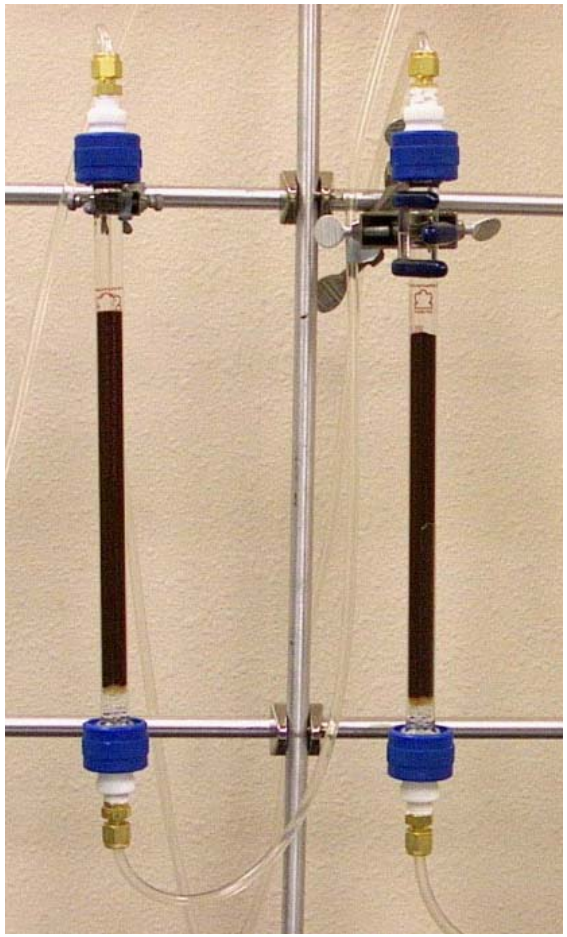
Predicting Diffusion and Transport:
Rapid Small Scale Column Tests



Proportional
Diffusivity design

- Reduce media sizes and column diameter
- Use higher hydraulic loading rate and shorter EBCT
- Dimensional analysis and similitude
- Tests take days (CD) to weeks (PD)

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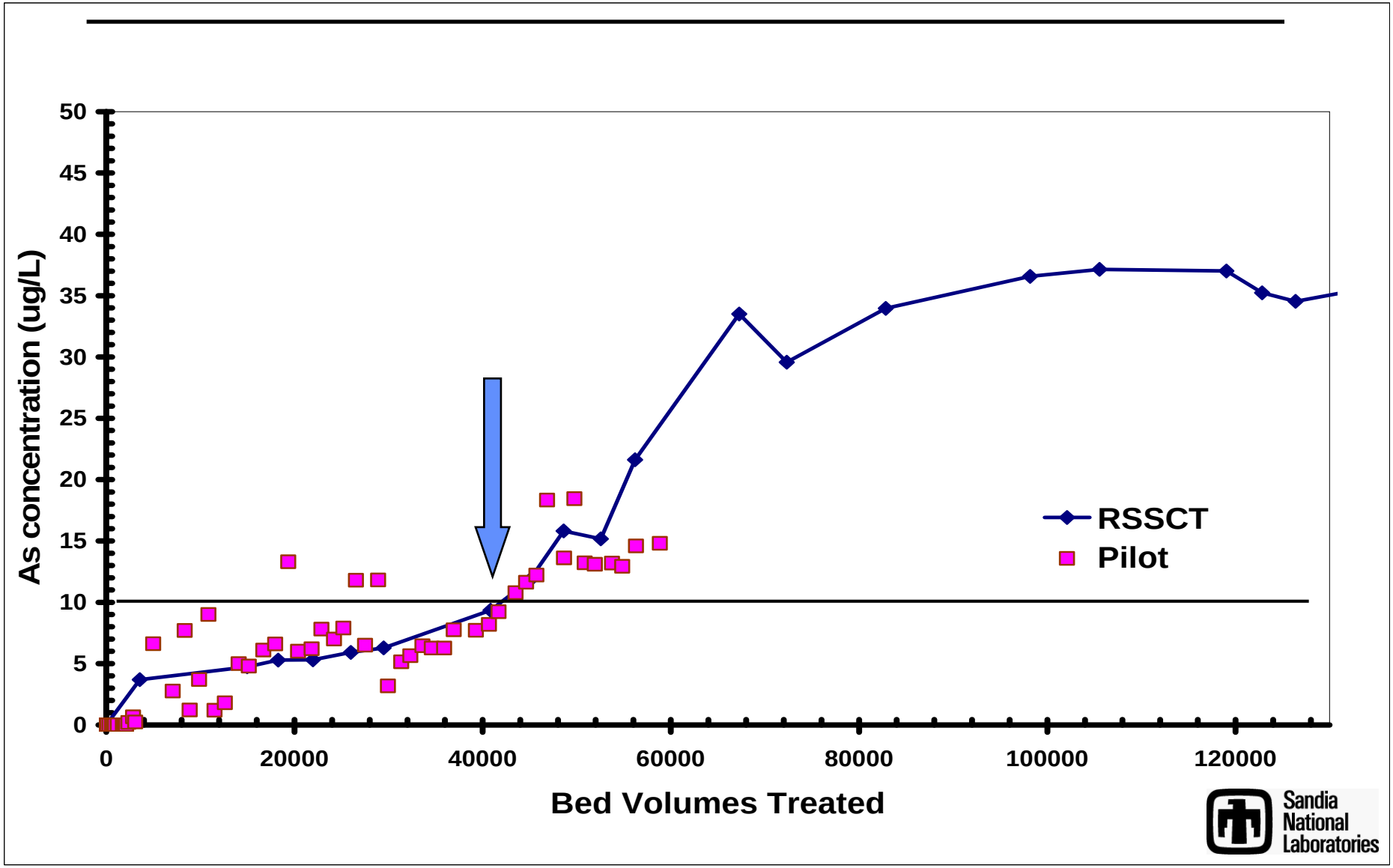
Socorro I Pilot and RSSCT Breakthrough Curves for E33 (4 min. EBCT)



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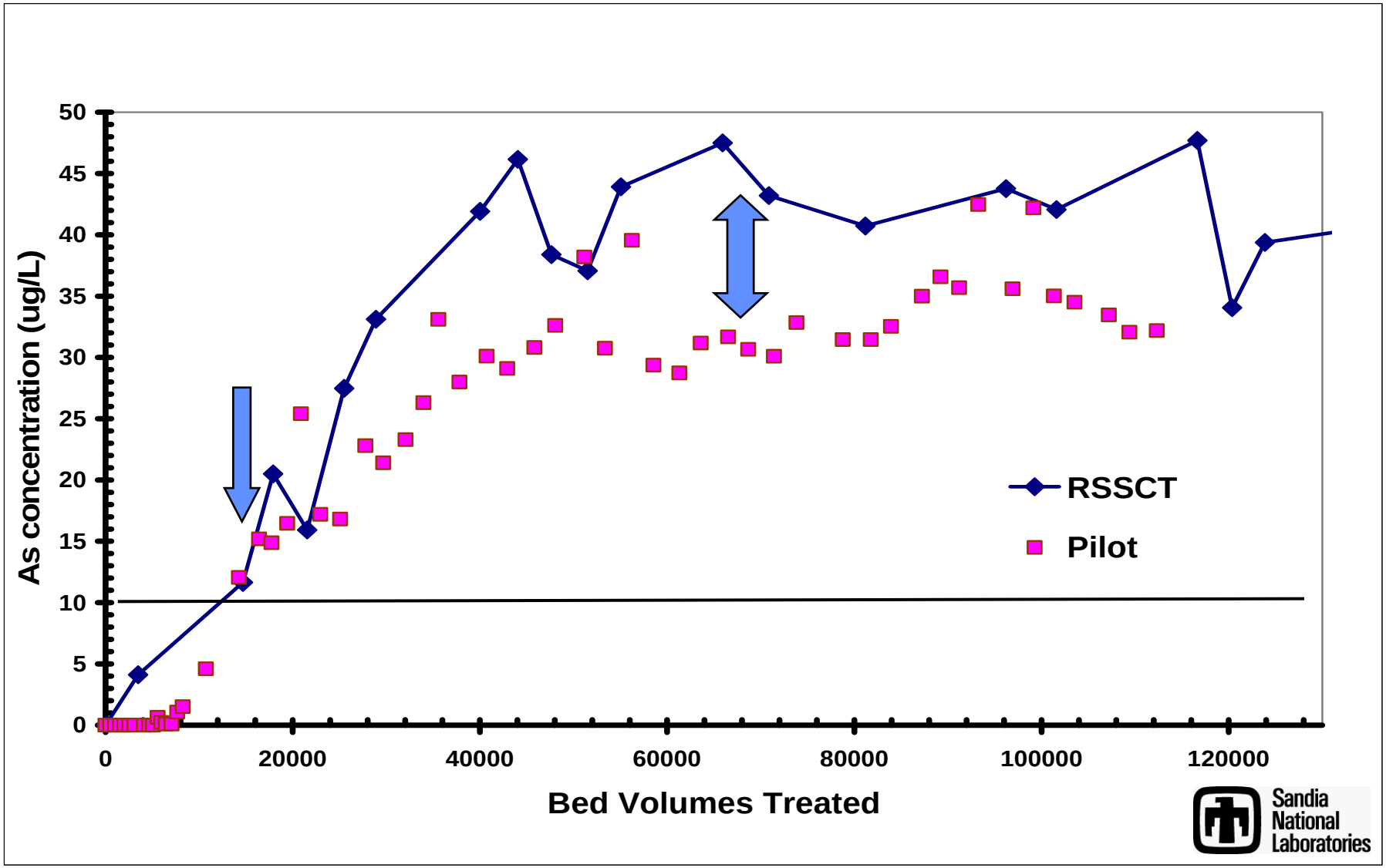
Pilot and RSSCT Breakthrough Curves for Metsorb Media



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Estimates of Arsenic Sorption Capacity from Different Tests (Socorro Phase I)

	E33 (FeOOH)	ARM200 (FeOOH)	Metsorb (TiO_2)
BV to 10ppb (pilot)	43,000	8,600	13,000
As at 10ppb (pilot)	3.56 mg/g	0.6 mg/g	0.7 mg/g
BV to 10ppb (RSSCT)	43,000 (PD)	6000 (CD)	12,800 (PD)
As at 10 ppb (RSSCT)	3.39 mg/g (PD)	0.42 mg/g (CD)	0.69 mg/g (PD)
As at 10 ppb (Freundlich)	5.0 mg/g	3.6 mg/g	1.2 mg/g

BV = bed volumes, PD = proportional diffusivity, CD = constant diffusivity

As = capacity calculated from loading or batch test

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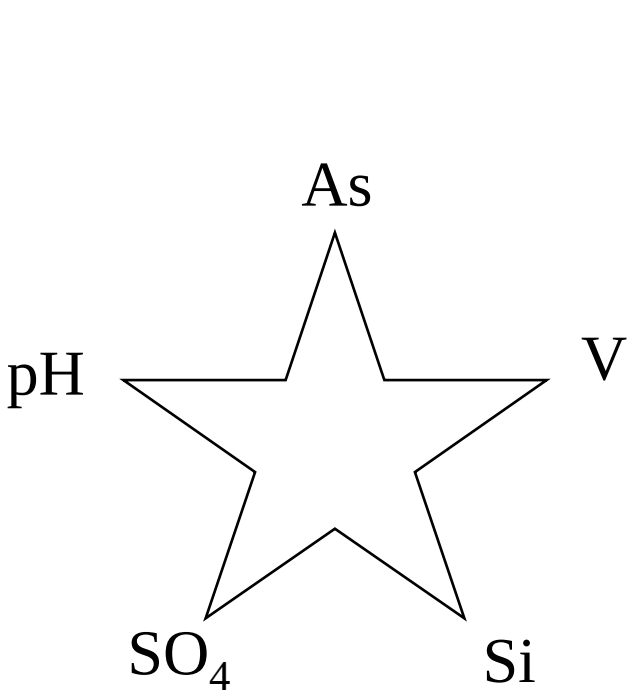
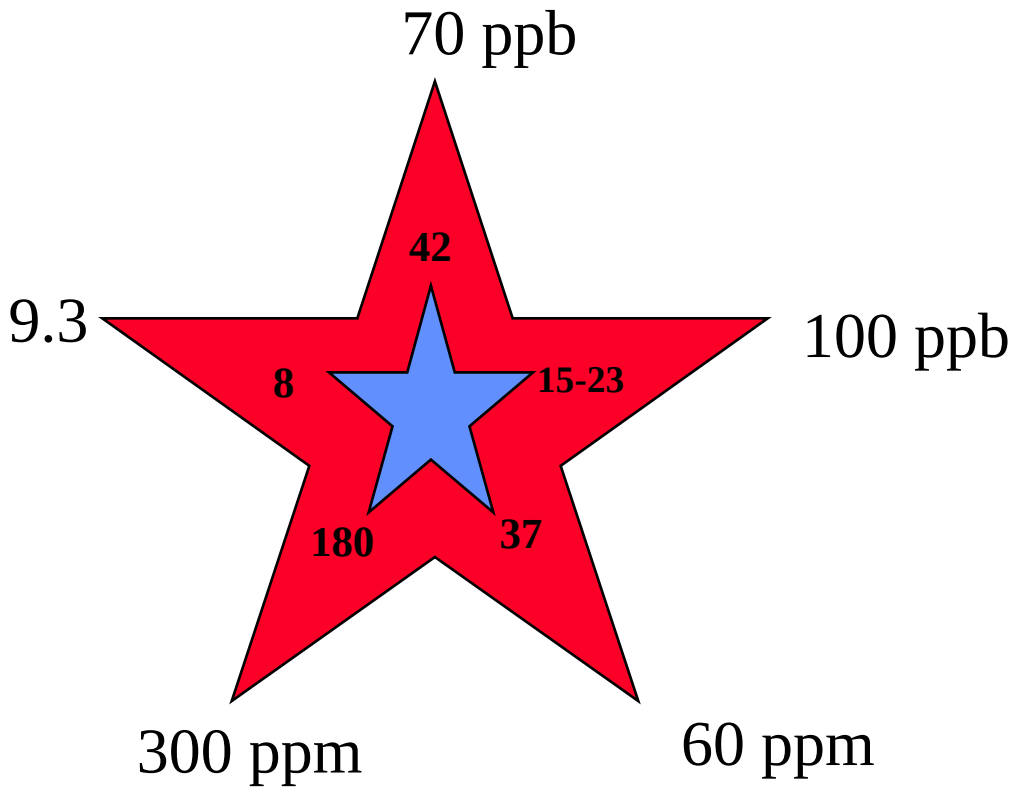
Efforts to Expand Range of Test Conditions





= conditions examined

= new conditions

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Simple Models to Predict Sorbent Bed Capacity for New Conditions

- **Isotherm Model for Media Replacement**
  - Gary Amy at CSU (AwwaRF, 2004; WERC, 2006)
- **RSSCT model for Bed Volumes to BT**
  - A. Aragon at SNL (SNL-AWTP, 2006)
- **Klinkenberg model for Bed Volumes to BT**
  - S. Deng, NMSU (SNL-AWTP, 2007)
- **Vendors' models**
  - Based on multiple installation and different water chemistries
  - May be proprietary

All models being evaluated as data and $ permit.

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Isotherm prediction (Amy et al. 2004)

- **Multivariate analysis based on parametric chemical studies with selected media over range of water chemistries.**
- **Freundlich Isotherm for E33**

$$Q = K_F \times [As]^{1/n}$$

$K_F = 0.813 - 0.16442 \times (pH-6.0) - 0.001544 \times (PO_4) - 0.01936 \times (SiO_2) - 0.015267 \times (V)$

$1/n = 0.1066 + 0.090358 \times (pH-6.0) - 0.0000654 \times (PO4) + 0.018384 \times (SiO2) + 0.001825 \times (V)$

  - $R^2 = 52\%$; adjust for pH (7.5 to 8.5) and PO_4 (100 – 250 ppb)

- **Available from AwwaRF and WERC**

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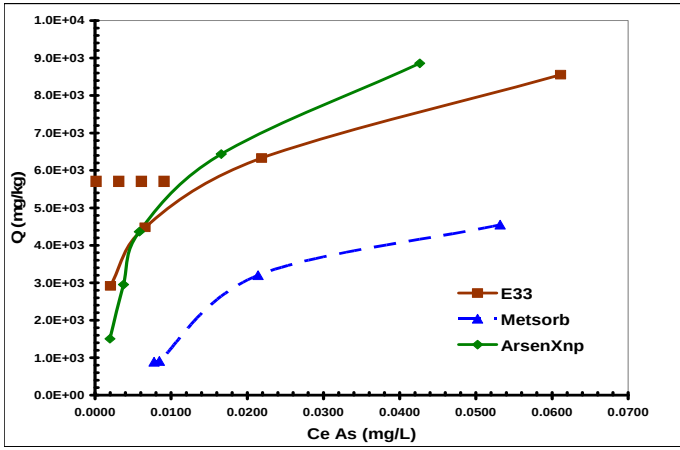
Isotherm Model for Media Replacement



Calculate K_f and 1/n as function of pH, V, PO_4, SiO_2

Apply Freundlich Isotherm to calculate As adsorption capacity (μg As/mg-media)

Calculate media run length (days) per vessel
Calculate number media replacements per year

$$= \frac{\text{As capacity x Media mass}}{[As_{(in)} - As_{(eff)}] \text{ x ave. flow}}$$

Mass spent media /yr = number replacements x media mass/vessel

Obtain cost of media/yr

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Parametric RSSCT studies with E33:
Rapid tests of effects of water chemistry

Parameter	"High" Value	"Low" Value
Arsenic*	100 ug/L	20 ug/L
Vanadium*	60 ug/L	0
Silica*	60 mg/L	0
pH*	9.0	5.0
EBCT (simulated)	5 min	3 min

* Nominal Nationwide groundwater concentration ranges for these constituents are taken from the USGS NAWQA Data Warehouse for Groundwater

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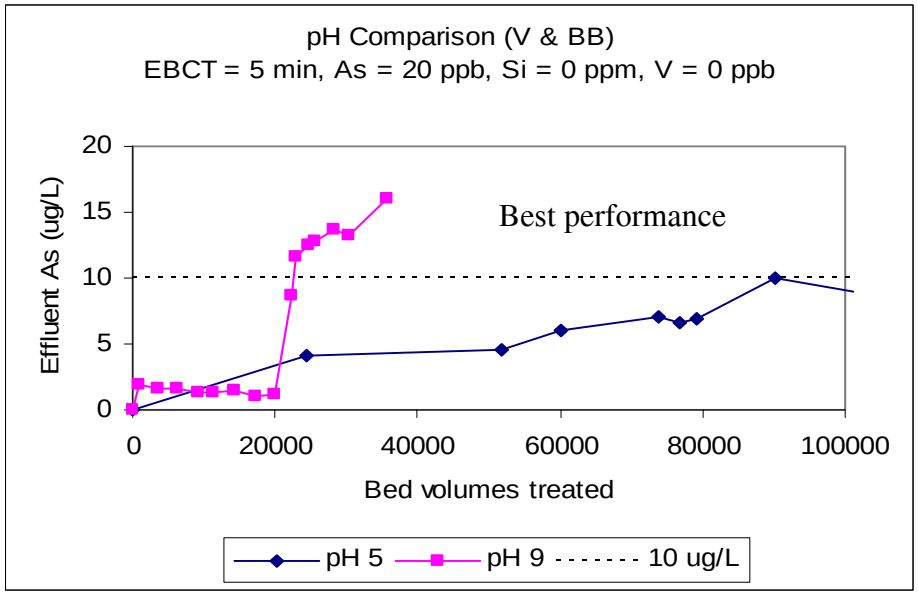
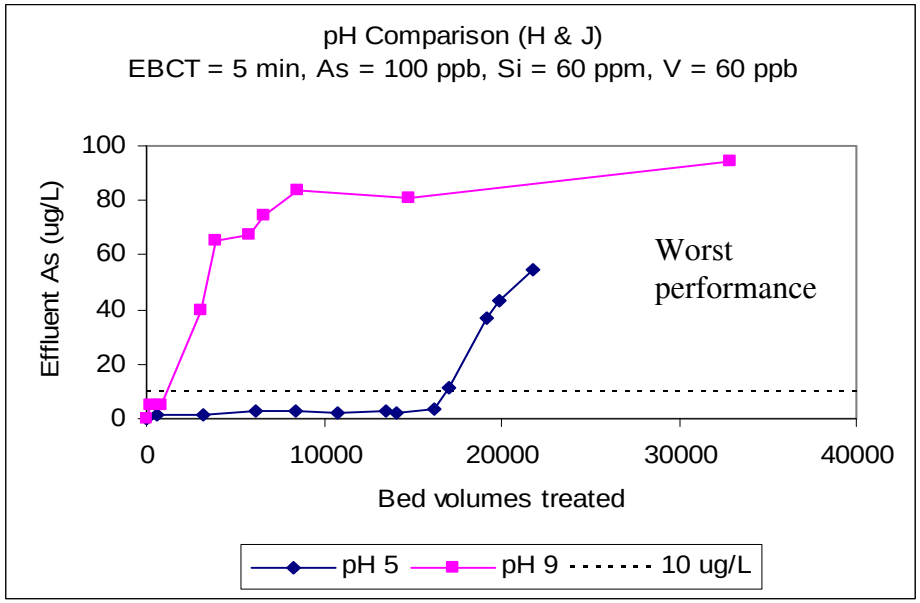
E33 Arsenic Breakthrough Comparisons



E33 consistently performs much better at pH 5 (vs. pH 9) regardless of other water chemistry parameters



Difference in performance of at least 3x (up to 18x)

BV = 116797 - 9433 pH - 127 Si - 232 V - 238 As

R^2 = 87% (no PO_4 dependence)

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Klinkenberg Model (1948)

- **Models ratio of adsorbent loading to the equilibrium adsorption amount at a given location and time.**
- **Can be programmed in Excel**

$$\frac{c}{c_F} \approx \frac{1}{2}\left[1+\mathrm{erf}\left(\sqrt{\tau}-\sqrt{\xi}+\frac{1}{8\sqrt{\tau}}+\frac{1}{8\sqrt{\xi}}\right)\right]$$

function of influent c_F, porosity, position, velocity, sorption, mass transfer kinetics

- **Assumptions**

(1) Isothermal conditions;

(2) No axial dispersion;

(3) Linear driving force for mass transfer

(4) Linear adsorption equilibrium, i.e. constant K_d

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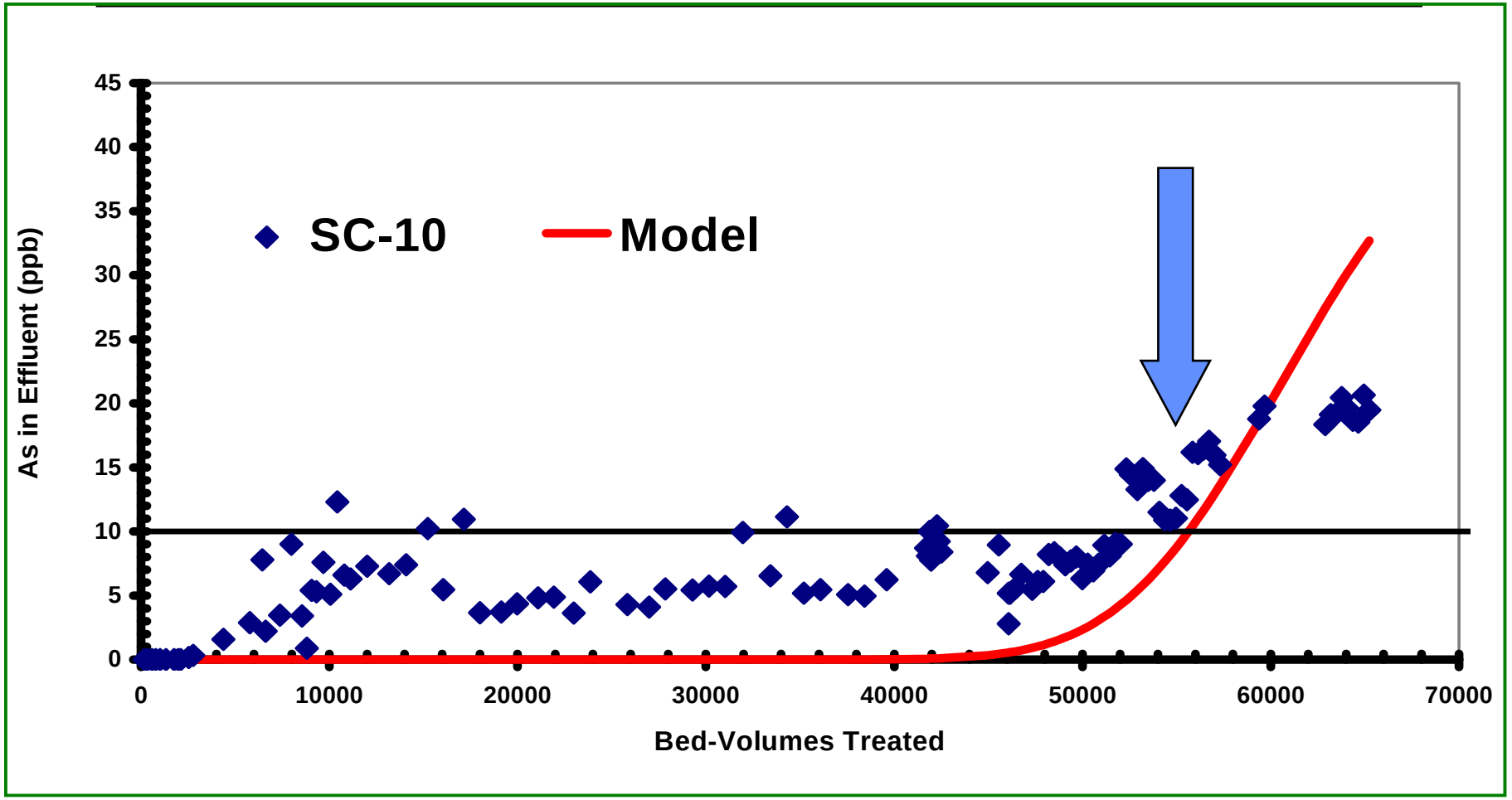
Klinkenberg Model for E33 (Socorro Phase I)



Comparison between Breakthrough Curves Obtained in Socorro Pilot Test SC-10 with Predictions from Klinkenberg Model.

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Outline of Talk

- Background – why we have a new As MCL.
- Arsenic Water Technology Partnership
  - Screening of technologies for pilot studies
  - Sandia Labs Pilot Test program
- Frontiers of Science
  - Understanding media performance
  - Rapid testing techniques
- What this all means in the real world
  - Helping communities deal with the new Standard
  - Sandia arsenic website
  - NM Small Business Assistance program

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Helping Communities

- **Information gathered at Vendors Forum and Pilots available on Sandia Pilot project website:**
  - **http://www.sandia.gov/water/arsenic.htm**
- **WERC developed Comprehensive Arsenic Tool (CoAsT)**
  - **available at: http://wercstation.nmsu.edu:8080/arsenic/AsTree.dsb**

  Summaries of BATs
    - **Several cost models**
    - **Decision tree**
    - **Beta-version of rate structure tool**
- **Sandia Rural Outreach Program**
  - **Summary report for communities in New Mexico**
- **NM Small Business Assistance Program**

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Arsenic Water Technology Partnership
Pilot Demonstration Project

- Pilot Demo Project Home
- Technology Evaluation
- Pilot Demonstrations
- Outreach
- Publications
- Partners
- Contacts

The **Arsenic Water Technology Partnership** is supported with a $13 million Congressional appropriation through the U.S. Department of Energy. The program is a multi-year effort designed to move innovative technologies from the bench-scale to pilot scale demonstration. This program will enable water utilities, particularly those serving small, rural communities and Indian tribes, to implement the most cost-effective solutions to their arsenic treatment needs. This goal is being met by carrying out three activities:

- **conducting research to develop innovative, arsenic removal technologies with a focus on reducing energy costs, minimizing operating costs, and minimizing quantities of waste;**
- **demonstrating the applicability of innovative technologies to a range of water chemistries, geographic locales, and system sizes; and**
- **evaluating the cost effectiveness of these technologies and providing education, training, and technology transfer assistance to user communities.**

The Awwa Research Foundation (AwwaRF) has managed the bench-scale research programs. WERC (A Consortium for Environmental Education and Technology Development) is evaluating the economic feasibility of the technologies investigated and conducting community education/technology transfer activities. Sandia National Laboratories (SNL) manages the pilot-scale demonstration program. During the period 2004-2006, Sandia National Laboratories has conducted pilot treatment demonstrations at six sites. Pilot communities and technologies were matched to examine a wide range of alternative technologies and site conditions. The classes of technologies tested include 1) Continuous Flow Systems (ion exchange, metal oxyhydroxides sorbents), 2) Batch Systems (Coagulation/Microfiltration), and 3) Reverse Osmosis. This website serves as a gateway to the activities supported by Sandia National Laboratories as part of the Arsenic Water Technology Partnership. Links are provided to:

- **Evaluation of innovative commercial arsenic treatment technologies**
- **Educational Short Courses and Vendors Forums held as part of the New Mexico Environmental Health Conferences in 2003 - 2005.**
- **Results of Pilot Demonstrations**
- **Project publications**
- **Activities of other members of the Arsenic Water Technology Partnership**

Arsenic Water Technology Partnership
Pilot Demonstration Project
Pilot Demonstrations

Overview of Pilot Demonstrations

Siegel, M.D., Dwyer, B., Aragon, A. and Everett, R. 2005. *Pilot Demonstrations of Arsenic Treatment Technologies in the U.S. Department of Energy, Arsenic Water Technology Partnership Program* [pdf 800kb]
SAND2005-1909C, Sandia National Laboratories, Albuquerque, NM.

Malynda Aragon, 2006. *Pilot Demonstrations of Arsenic Removal Technologies - Sandia National Laboratories* [pdf 612kb]
SAND2006-7639P, Sandia National Laboratories, Albuquerque, NM.

Sandia National Laboratories Arsenic Treatment Technology Demonstration Program [pdf 1.4mb]
Presented at the American Water Works Association Inorganics Contaminants Conference, January 31, 2006.

Pilot Tests of Adsorptive Media Arsenic Treatment Technologies in the Arsenic Water Technology Partnership 2006-0372C [pdf 811kb]
Presented at the National Groundwater Association Meeting on Naturally Occurring Contaminants, Albuquerque, NM, February 6, 2006.

Pilot Test Sites News Releases

- Socorro, New Mexico
- Anthony (Desert Sands), New Mexico
- Rio Rancho, New Mexico
- Jemez Pueblo, New Mexico
- Pine Hill, Ramah Navajo Reservation (New Mexico)
- Weatherford, Oklahoma

Program Contact:
Malcolm Siegel, Sandia National Laboratories
Phone: 505-844-5426, FAX: 505-844-7354 or Email: msiegel@sandia.gov

Awwa Research

WERC

Sandia Water Initiative

t Demo Project Home
Technology Evaluation
Pilot emonstrations
Outreach
Publications
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Contacts

Introduction

The decrease of the drinking water standard (MCL) for arsenic from 50 µ/L to 10 µ/L in January 2006 could lead to significant increases in the cost of water for many rural systems throughout the United States. The Arsenic Water Technology Partnership (AWTP), a collaborative effort of Sandia National Laboratories, the Awwa Research Foundation (AwwaRF) and WERC: A Consortium for Environmental Education and Technology Development was formed to address this problem by developing and testing novel treatment technologies that could potentially reduce the costs of arsenic treatment. Each of the Partners develops or evaluates new technologies in their respective programs: AwwaRF manages a bench-scale research program through a series of competitive grants; WERC hosts an annual contest in which university students compete to provide the best solution to a design challenge involving arsenic treatment; Sandia National Labs has sponsored educational Short Courses on arsenic removal technology and evaluated cutting-edge commercial products in three annual Vendors Forums held during the annual New Mexico Environmental Health Conferences (NMEHC) in 2003, 2004 and 2005. The most promising of the technologies from these three programs are pilot tested at several field sites in collaboration with local water utilities.

This website describes the efforts of Sandia National Laboratories to evaluate commercial technologies for the pilot test program from 2003 to 2006. The educational Short Courses held at the NMEHC included invited talks on aspects of arsenic occurrence, health effects and treatment technologies. The Vendors Forums were designed to allow vendors of commercial technologies to present product descriptions to the conference participants and to allow objective evaluation by technical experts. During a closed session, the technologies were reviewed by teams of recognized experts in water treatment and related fields and were assigned numerical scores based on expected performance and costs. Table 1 lists all the companies that participated in the Forums, identifies their products and provides electronic links to points of contacts or company websites. Table 2 describes the rankings of technologies for each of the 3 Vendors Forums and identifies those being pilot tested at the field scale by Sandia National Laboratories.

Other technologies were evaluated through other methods such as by independent review of product performance and cost by Sandia staff, technical review by the Technical Advisory Committee and the Partnership Management Committee of the AWTP. Several of these technologies were chosen for pilot scale demonstrations; Table 3 provides descriptions of these products. A list of the technologies being tested at each of the 5 pilot sites is given in Table 4.

Table 1. Vendor Forum Participants

All of the technologies that were reviewed are described in this website. Treatment methods are categorized as adsorptive media, coagulation/filtration/membranes or other technologies. An alphabetical index to all technologies is also provided. Other information about the technologies and related topics can be found in two summary reports and the websites for each of the Short Courses and Vendors Forums, which include links to the presentations given at these events.

Treatment Methods

Category Listing

Summary Reports

- *Development and Evaluation of Innovative Arsenic Adsorption Technologies for Drinking Water by the Arsenic Water Technology Partnership*, SAND2006-0113C [pdf 248kb], National Groundwater Association Meeting on Naturally Occurring Contaminants, Albuquerque, NM, February 6, 2006
- Malcolm Siegel, Paul McConnell, Randy Everett, Carolyn Kirby 2006. *Arsenic Treatment Technology Vendors Forums Summary Report* [pdf 220kb]
SAND2006-5423, Sandia National Laboratories, Albuquerque, NM.

Event Websites

- Arsenic Treatment Technology Short Courses
- Arsenic Treatment Technology Vendors Forums

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Awwa Research Foundation
Advancing the

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Sandia Water Initiative
SAFETY · SECURITY · SUSTAINABILITY

Demo Project Home
Technology Evaluation
Pilot Demonstrations
Outreach
Publications
Partners
Contacts

James L. Krumhansl, Kathleen C. Holt, Heather Himmelberger, Susan Butler, Matt Ziegler, and Bruce Thomson, 2007. *Summary of Resources Available to Small Water Systems for Meeting the 10 ppb Arsenic Drinking Water Limit* [pdf 1mb] SAND2006-6943, Sandia National Laboratories, Albuquerque, NM.

NM Small Business Assistance Program

- **Objective**
  - Assist small NM businesses in water treatment problems to grow their business
- **Qualified businesses**
  - Satisfy definition of ‘small business’
  - NM tax ID
  - <500 employees and/or cap on annual revenues
- **Free technical Assistance**
  - Urban - $10,000/yr
  - Rural - $20,000/yr
- **Applications still being accepted for 2008**

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Possible Assistance by Sandia

- **Sandia National Labs can:**
  - **Provide training on tools and data obtained in AWTP**
  - **Provide initial analysis of options for arsenic treatment.**
  - **Screen potential treatment vendors.**
  - **Coordinate pilot tests by vendors.**
  - **Provide rapid turn-around time for water analyses (not EPA certified) to aid design and tests.**
  - **Review proposals from companies for water treatment systems.**
- **Sandia cannot compete with private businesses.**

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Current and Future Projects

Paakweree Water Cooperative

New Mexico Utilities

Pine Hill School

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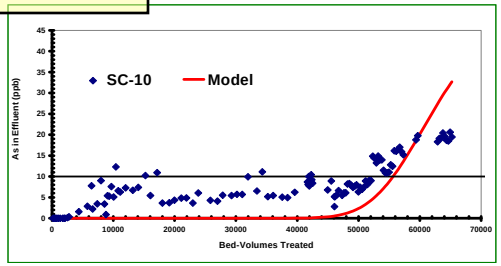
Summary - Research Program - Applications

Use rapid testing methods and models to to narrow down choices for the most effective adsorptive treatment technology for small systems.

Full scale treatment
12-24 months

Pilot scale
6-12 months

RSSCT & isotherm
Days-weeks



Models: days- hrs

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Take Home Message

1. Don’t panic! – the water won’t kill you right away.
2. Don’t make hasty decisions about water treatment system for arsenic removal.
3. The right system for your community depends on:
    - Available (non-treatment) options
    - Financing options
    - Operator training
    - Existing infrastructure
    - Water chemistry
4. There’s no magic bullet!

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For More Information and Assistance :

Arsenic Partnership Website

http://www.arsenicpartners.org/

Sandia Website

http://www.sandia.gov/water/arsenic

→ **Papers, Presentations, Vendor Information, Pilot Results**

WERC CoAsT Website

http://www.werc.net

→ **Click on Outreach tab, then CoAsT**

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Thank you for your attention

Questions?

msiegel@sandia.gov

505-844-5426

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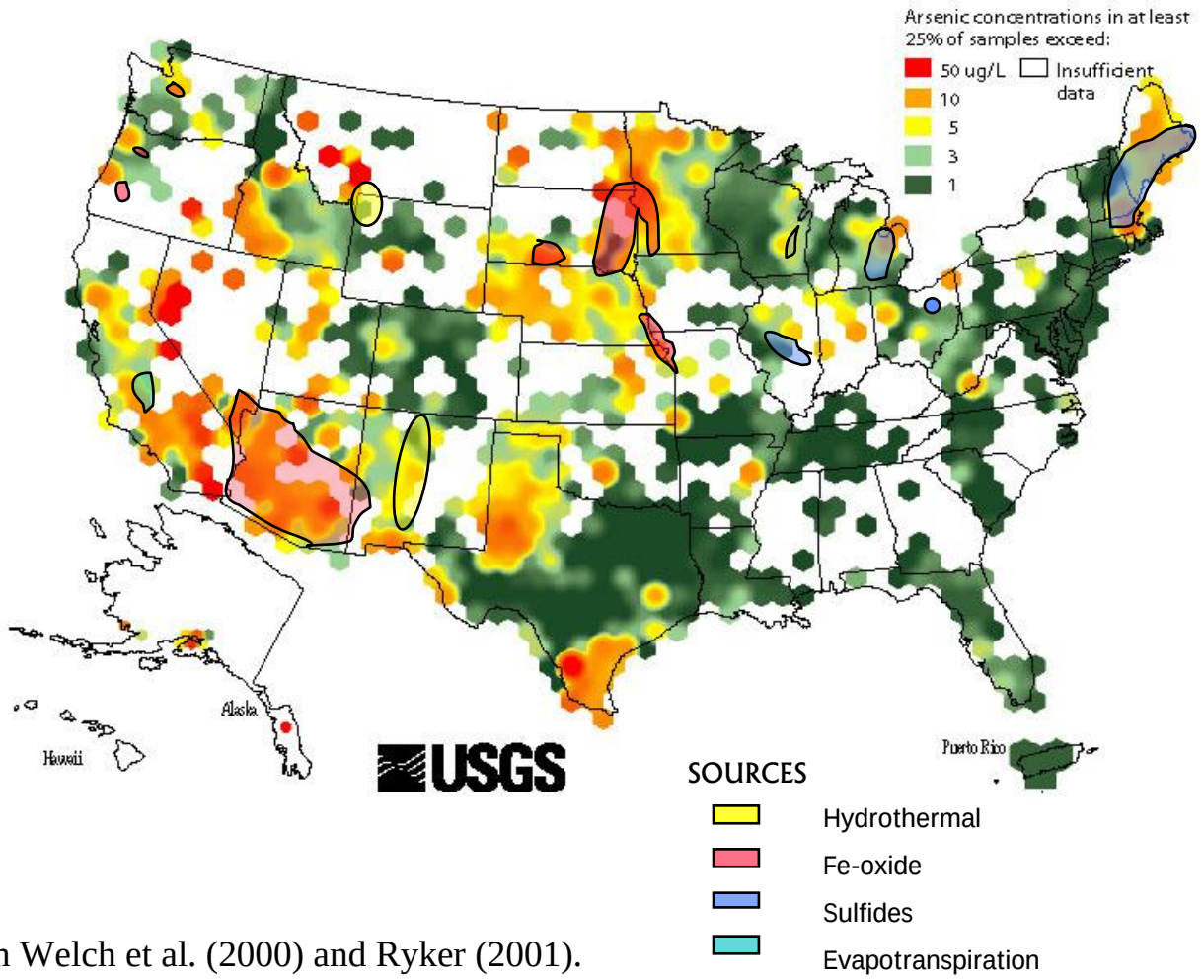
Arsenic Sources and Occurrences



Adapted from Welch et al. (2000) and Ryker (2001).

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Things we looked for in pilot sites

- As concentration (>10 ppb)
- Example ground water composition that will help other communities
  - pH, TDS, foulants such as Fe, Mn, silica, and organics
  - As(III)/As(V)
  - Competing ions (V, SO_4, etc.)
  - Other contaminants of concern/benefit (e.g, Ra, U, ClO_4, F)
- Small size of system to be treated (< 10,000 users)
- Community support facilitates rapid deployment
  - Water utility
  - Municipal government
- Ability to deal with residuals/treated effluent
- Rural and Native American communities that would benefit from assistance

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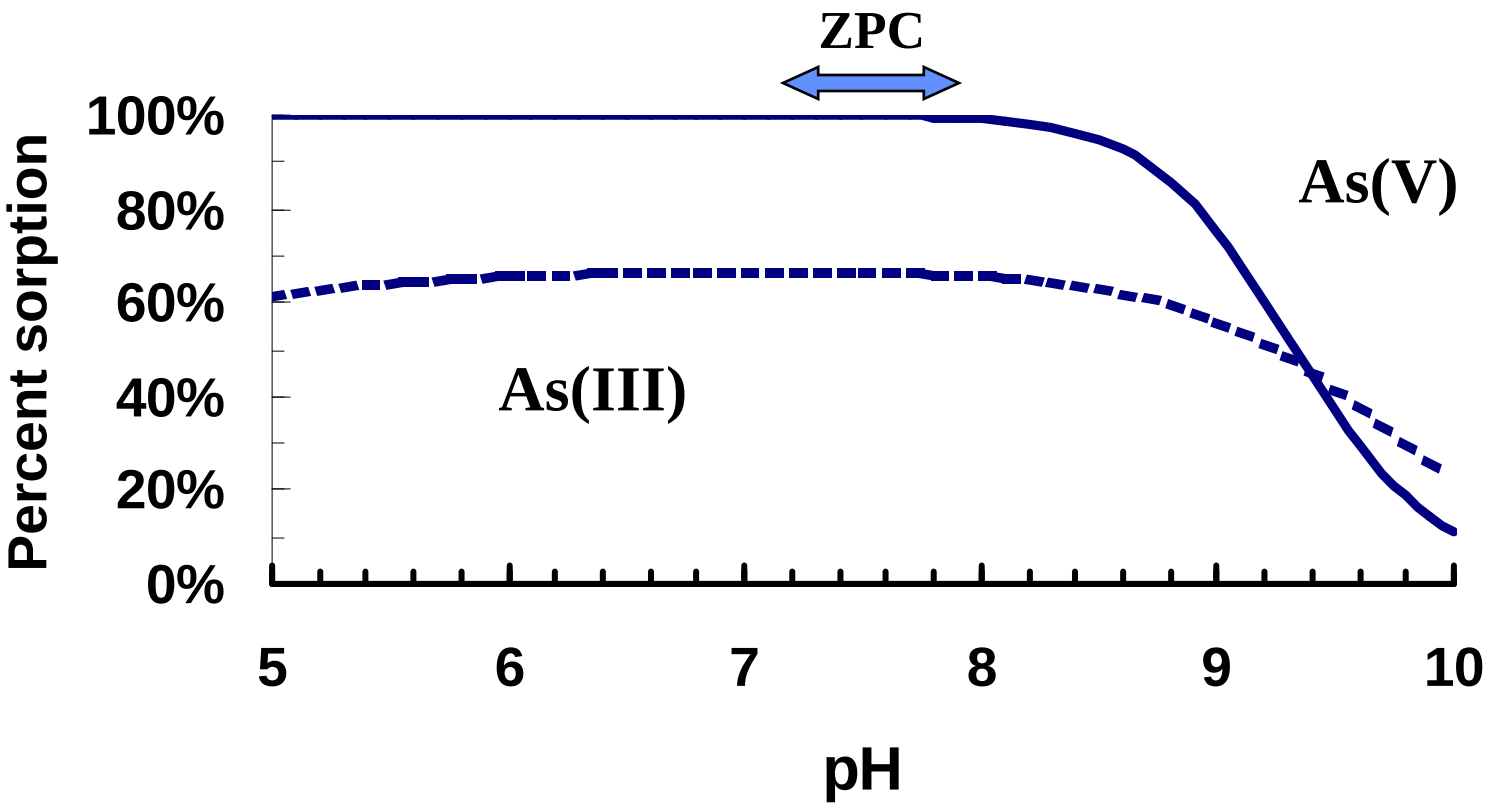
Chemical Compositions of Media

Media	Constituents (XRD)	Dominant Elements (EDS)
Isolux 302M	Amorphous zirconium oxide/hydroxide	Zr, O
Metsorb	Crystalline TiO_2 (*Anatase*)	Ti, O
ARM200	Amorphous Iron oxide/hydroxide (or very poorly crystalline *Hematite*)	Fe, O
ArsenX^{np}	Amorphous iron oxide/hydroxide Resin impregnatation	Fe, O, C
E33	Iron oxide/hydroxide (*Goethite*)	Fe, O

pH and Sorption by adsorptive media
Example: $Fe(OH)_3$



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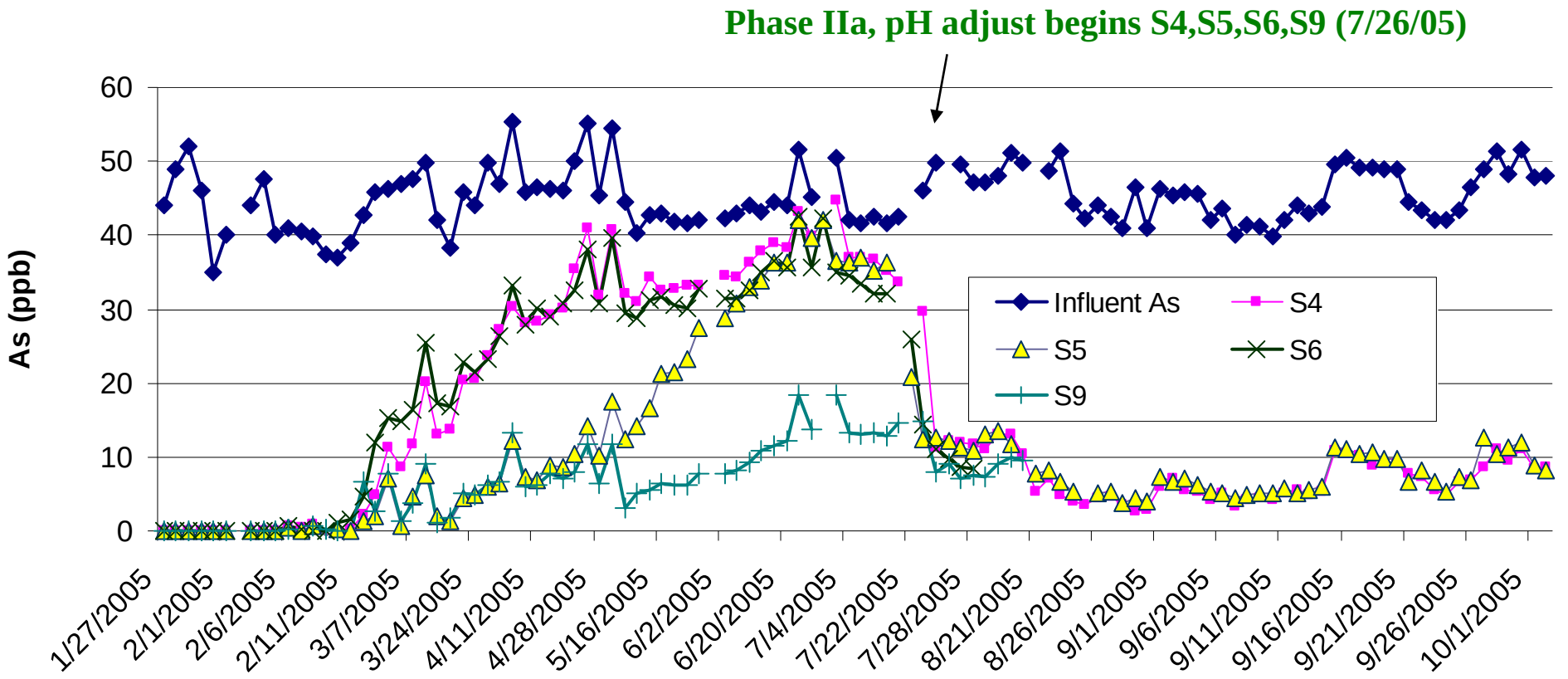
Socorro Pilot Phase I and IIa Events

S4 = ARM200 (FeOx); S5 = AsXnp (resin); S6 = Metsorb (TiOx); S9 = E33 (FeOx)



Not a linear scale!

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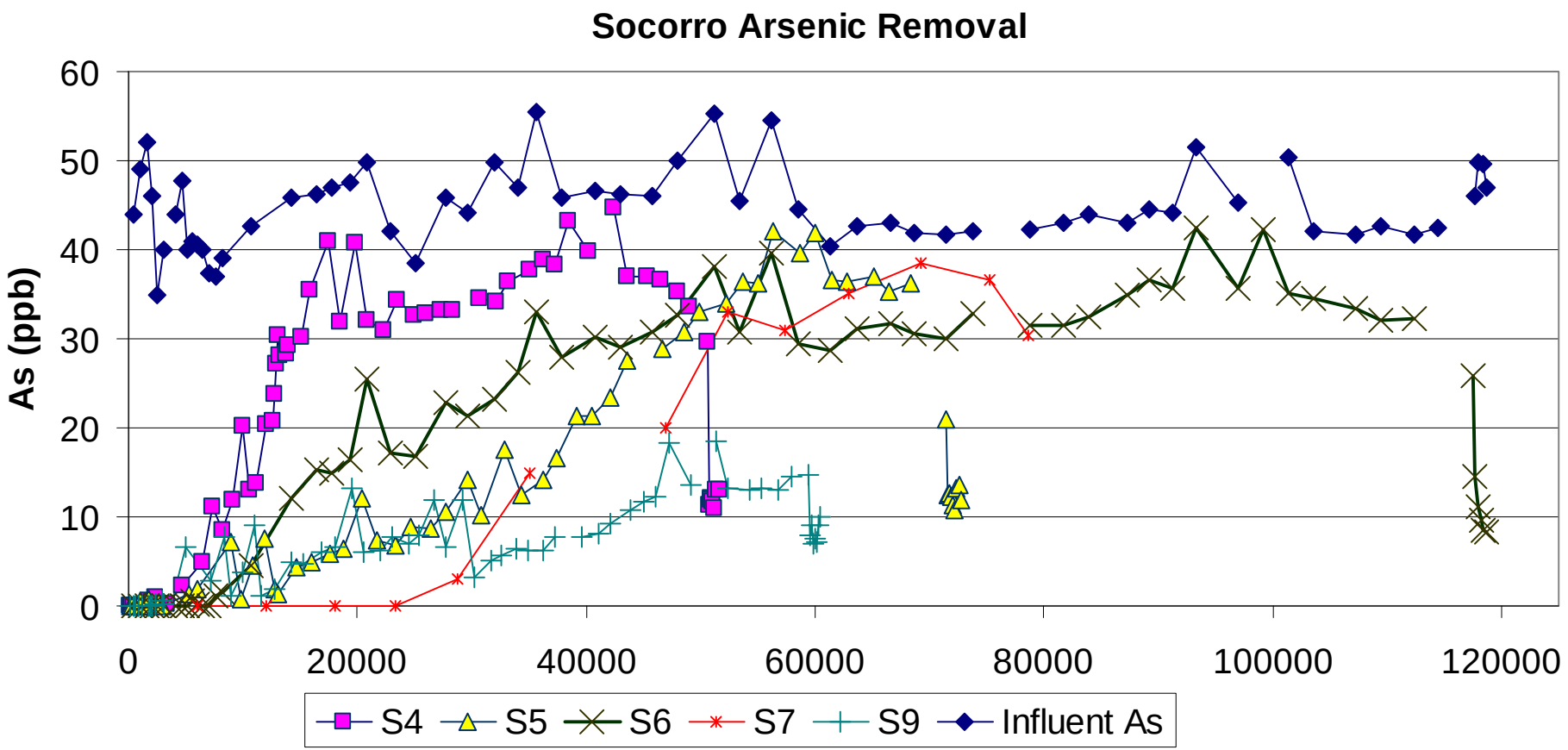
Media Performance Socorro, NM

S4 = ARM200 (FeOx); S5 = AsXnp (resin); S6 = Metsorb (TiOx); S7 = Isolux (ZrOx); S9 = E33 (FeOx)



*AsXnp batch was defective, ARM200 was pre-production batch

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Research Program - Components

- **Materials characterization**
  - **Pre-test and post studies, temperature-ageing studies**
  - **XRD, Surface area (BET), pore size distribution**
  - **Particle morphology and surface chemistry**
  - **Attrition loss**
  - **Post-mortem pore fluids and solids**
- **Batch sorption studies**
  - **Kinetic (15^{o}C and 40^{o}C)**
  - **Isotherms (linear, Freundlich, Langmuir)**
- **Rapid small scale column tests (RSSCTS)**
- **Develop simple model that could predict media performance from Lab tests**